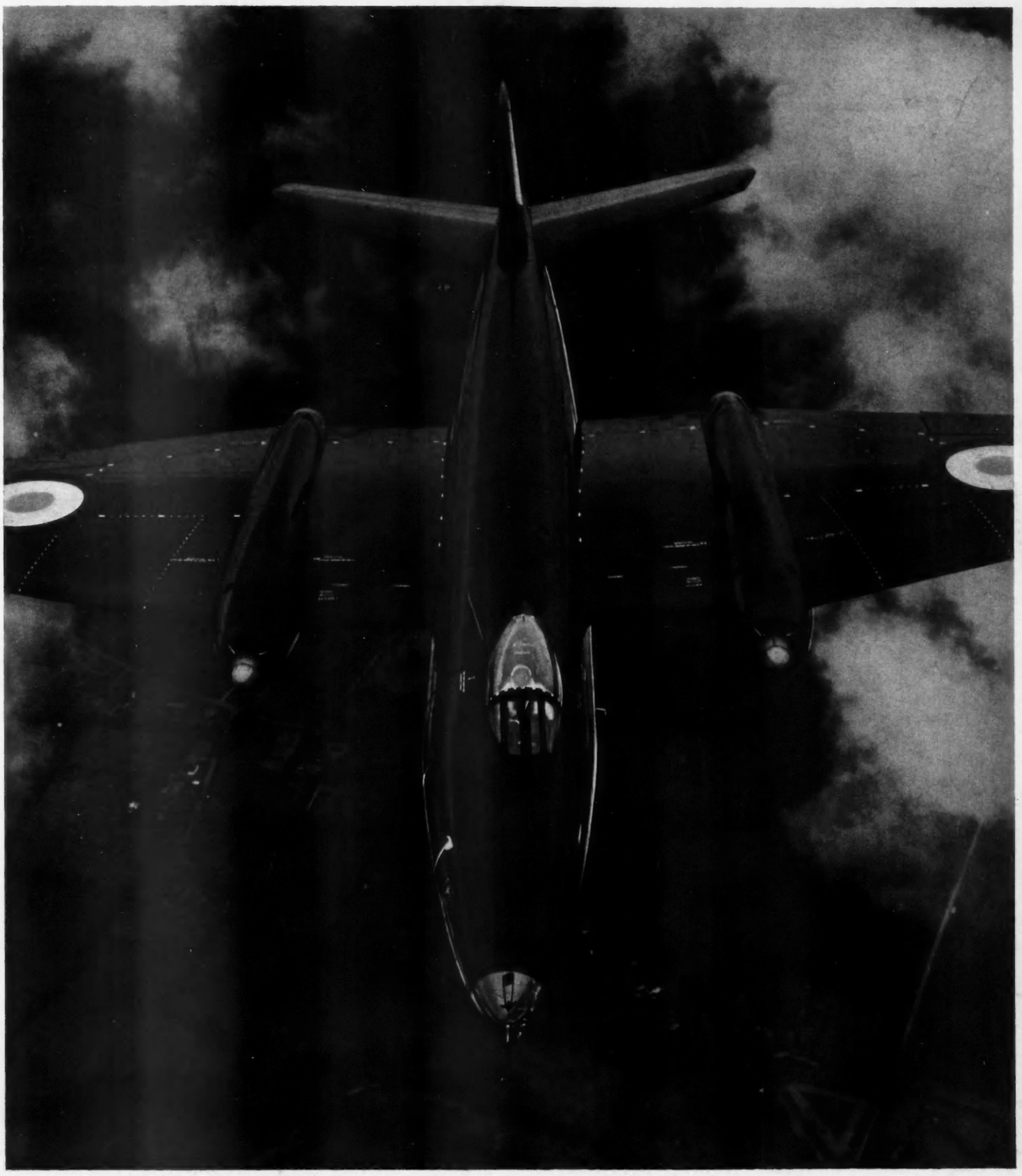
ENGINEERING

An Illustrated Weekly Journal

35 & 36 BEDFORD STREET, STRAND, LONDON, W.C.2 — TELEPHONE: TEMPLE BAR 3663

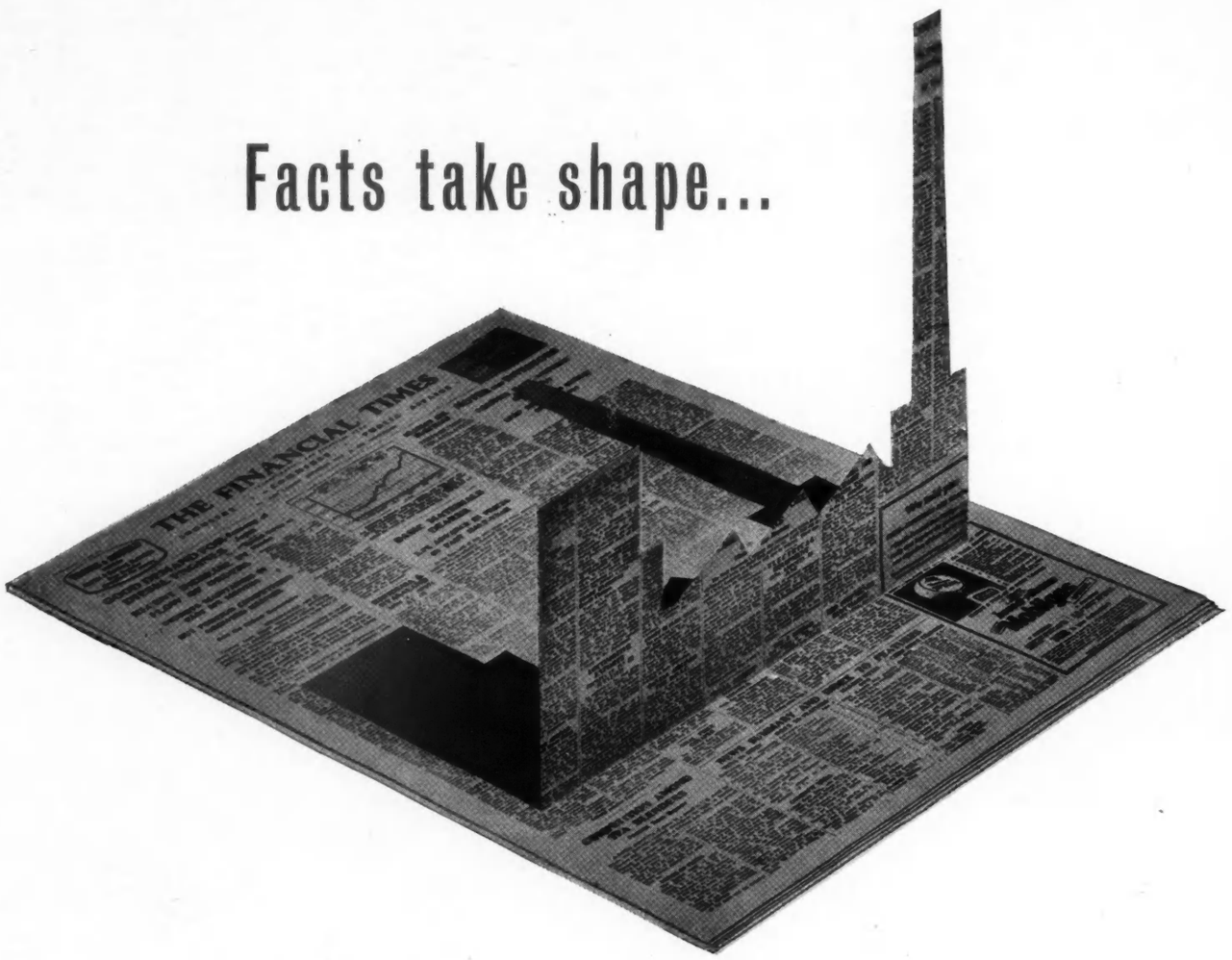
Vol. 178 No. 4634 — LONDON, FRIDAY, NOVEMBER 19, 1954 — Price 2s.

UNIVERSITY OF MICHIGAN
DEC 9 1954
ENGINEERING LIBRARY



CANBERRA B8 NIGHT INTRUDER AIRCRAFT

Facts take shape...

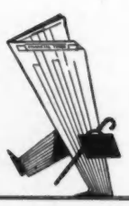


Do you sometimes yawn over the facts and figures of industry? They can be hard going unless you have discovered THE FINANCIAL TIMES as a refreshing daily tonic. This well-respected newspaper—read by directors, engineers and all business men who want to keep ahead—gives industrial news a new look without sacrificing an iota of truth. There is infinite pleasure to be found in the cool clear reporting of THE FINANCIAL TIMES and in its concise articles and features. As you read, facts take shape and form, and puzzling situations become clear. In the space of a morning train journey you can absorb the essence of the day's news from industry and commerce, and appear at your office stimulated and well-informed. Try reading THE FINANCIAL TIMES every day for a week—at the end of that time we believe you will wonder how you ever managed without it.

Men of industry read

THE FINANCIAL TIMES

every day



THE FINANCIAL TIMES · 72 COLEMAN STREET · LONDON E.C·2

ENGINEERING

An Illustrated Weekly Journal

Vol. 178 No. 4634 NOVEMBER 19, 1954

Leading Article
Flying Machines 645

Principal Articles
Technical Evidence at the Comet Inquiry 648
Sir George Cayley : Early Flying Experiments 654
The Institution of Naval Architects Autumn Meeting. The Side Launching of Ships : Model and Full-Scale Experiments 655
Stresses in Short Beams : 2—Theoretical Analysis and Conclusions 656
Differential Analyser : The N.P.L.'s New Analogue Computer for Solving Differential Equations 659
Increasing the Thrust of Jet Engines 660
The Fishburn Coke-Oven Plant 661
Prestressed-Concrete Arched Silo : Three-Pinned Frames Covered with Pre-Cast Concrete Planks 665
The Public Works Congress and Exhibition: Some Road-Building Plant at Olympia 666
Electricity Supply in Jamaica 668
Electronic Fault-Finder 668
Automatic Control of Boilers : Fuel and Air Regulated by Grid-Controlled Rectifiers 669
"Sandwich" Materials to Resist High Temperatures 670
New Alloys for Permanent Magnets 672
Positive Displacement Rotary Pump : Bunkering Unit with Capacity of 1,500 Gallons per Minute 672
Testing and Running-In Tractor and Car Engines 673
Automatic Chain Lubricator : For Use with Conveyors 674
Time-Interval Recorder : Planning Machine and Vehicle Maintenance 674
Heavy-Duty Air-Line Coupling : For Pressures up to 300 lb. per square inch 674

Weekly Survey
America Approves the Turbo-Prop 646
The Small Firm 646
Selling Diesel Engines 646
Baghdad a Success 646
Trade Promotion by the F.B.I. 646
Ships and Shipping 646
Marine Engines 647
Welded Versus Seamless Tubes 647
Automatic Foundry 647
The Cycle and Motor Cycle Show 647
Non-Reflecting Glass 647

Personal 651
Business Changes 651
Obituary 651
Contracts 652
Letters to the Editor
Ease of Reading Printed Matter 652
Book Reviews
Coal : Its Formation and Composition 653
Trade Publications 653
Books Received 653
Launches and Trial Trips 664
Labour Notes 675
Notice of Meetings 676
News
Designing for the Eye : Form and Utility in Engineering Products 652
All-Aluminium Cars for Toronto Subway 658
Terminology in Industry 660

★ ★ ★

Published every Friday by Engineering Limited
35 & 36 *Bedford Street, Strand, London, W.C.2*
TELEGRAPHIC ADDRESS *Engineering, Lesquare, London* TELEPHONE *Temple Bar* 3663

Subscription Rates for 12 *months, Inland and Abroad* £5 10*s.*, *Canada* £5 5*s. Subscriptions for periods of less than* 12 *months are based on the price of a single copy including postage* [2*s.* 3*d.*]

FLYING MACHINES

ONLY 45 years ago, the first issue of *The Aero*, a weekly magazine, was published. Lord Brabazon, at that time Mr. J. T. C. Moore-Brabazon, had "made several short flights with the *Bird of Passage* at Shellness. His engine . . . has been thoroughly overhauled and tuned up by Short Bros., and is in splendid order. Unfortunately, he had a slight accident a fortnight ago, owing to a rudder wire sticking and causing the steering drum to slip round on the steering column without moving the rudder. His machine had risen from the ground in a few yards and was flying grandly, but the sticking of the rudder forced him to descend quickly, and as he landed on the turn instead of in a straight line he crumpled up the chassis of the machine somewhat and cracked some of the wooden *nacelle*, or cradle, which forms part of the main frame. Little other damage was done, and Short Bros. were rapidly putting the machine in order when we saw it last."

In those early issues of 1909 we can read the names of Mr. A. V. Roe and Mr. Handley Page; there are details of a proposed vertical-lift machine, a patent of the Wright brothers, a picture of Cody's first British Army aeroplane in flight, and a note to the effect that Monsieur Blériot hopes to complete his twelfth flying machine in a few weeks' time. Since those days aeroplanes have never been far from our thoughts. They have bombed our cities; they have saved our island. They have earned us millions of dollars; they have cost us millions of pounds. We have feared them; we have put all our faith in them. We have neglected them; we have devoted our greatest brains to them. At the present time we expect far too much from them. The British aircraft industry entered the post-war era handicapped by the fact that, during the war, they had had to concentrate on military aircraft, whereas American firms had been developing transport machines which, from a design point of view, were a better preparation for civil aircraft work. In spite of this disadvantage, the industry in a few years achieved miraculous progress. It is because of that achievement that the present setback, temporary though it is, has been a shock to the nation.

The debate in the House of Commons on Monday of this week revealed the intense interest and anxiety which everyone feels at the moment. The suggestion that the British Overseas Airways Corporation may wish to order some American aircraft, even with Rolls-Royce engines, has raised a storm of protest. If it is possible to take a detached view at this juncture it is important to recognise that every new aircraft is a risk, whether the design is British, American or any other nationality. In the older forms of transport—shipping and railways—the designers and operators have always been conservative in their adoption of new ideas—probably too conservative. It has always been held that any machine connected with the transport of passengers must, above all else, be safe. In aeronautics, however, international competition and the forcing influences of war have demanded rapid progress, even at the risk of some uncertainty regarding the safety of the aircraft. Though there may be changes in practice and administration designed to increase assurance in the future, there can be no abandonment of the aircraft industry's farseeing and experimental outlook. As Lord Brabazon remarked at the Court of Inquiry recently: "I do hope that the threat of having to face such an inquiry as this, with all its publicity, if anything goes wrong, will not stop adventurous spirits pioneering in the future."

The discussion in Parliament centred mainly on the wisdom of permitting B.O.A.C. to purchase American aircraft. It was unfortunate that this question should arise at this juncture, because there are bound to be occasions in the development of an air-line when the balance of advantage, taking everything into consideration (including the time factor, as well as technical design) is slightly in favour of a foreign machine, even if it is only a question of delivery dates.

The situation may well alter in a year, or even a few months, but an air-line corporation must not be blamed for wishing to adopt the most businesslike proposal. Air-line operators abroad should be the first to recognise this point of view, and so long as the British corporations do not positively reject the British industry's products, there is no occasion to regard the Corporation's proposals as a reflection on the industry. The Government will have to decide the question of purchasing American aircraft. Whatever decision is reached, overseas aircraft manufacturers and operators will be deluding themselves if they conclude that British firms are not still in the forefront. A year or two hence the present searching inquiry will be seen in true perspective—as a critical stage in the history of the industry, when, without doubting the ultimate good that will come of it, Parliament, the Civil Service, the aircraft firms and the air-line operators took stock of the position, reorganised as necessary, and then continued with added strength and efficiency. There will be some hard thinking about fundamentals in the next few months. British firms will emerge as even more formidable competitors than they have been in the past.

Weekly Survey

AMERICA APPROVES THE TURBO-PROP

Almost to a day two important announcements have been made about gas-turbine aircraft. On one hand the Civil Aeronautics Administration in the United States has cleared the outstanding points affecting an air-worthiness certificate for the propeller-turbine Vickers Viscount; on the other, the United States Air Force has grounded all its Super-Sabre jet fighters pending investigations into three crashes. It is now certain that turbo-prop machines will be in flight over the airlines of the world before jet aircraft is generally accepted. The Viscount will be in wide service by next year when Capital Airlines put their first three into operation on internal U.S. routes. The machines have already earned a high reputation in Europe.

Apart from the Viscount, now generally accepted as the outstanding aircraft for short and medium-distance travel throughout the world, there is the Britannia, which will bring the turbo-prop machine into long-distance service within two years. Another development is the number of aircraft companies, notably in the U.S., which have made arrangements to instal British turbo-prop engines in existing aircraft. Those operating companies throughout the world which have not hurried to accept the jet airliner are, of course, relieved to find that there is in fact an intermediate stage between the piston engine and the pure jet which can be adapted to existing airport facilities. The turbo-prop has had to take second place to the jet in the public's imagination but it has its compensations in offering air operators a gradual process of change rather than a revolution. The change will be all the slower since the delays now inevitable to jet aircraft mean a new lease of life to piston-engined aircraft, as the recent purchases by certain Continental European airlines of American DC-Cs show. The controversy which has arisen in the House of Commons this week on B.O.A.C.'s possible interest in the DC-7C and DC-7D (this last being the turbo-prop version of the DC-7 class) is discussed in the leader on page 645.

It is probable, however, that those abroad who think in terms of the turbo-prop gaining ground in the long run at the expense of the jet will be wrong. Irrespective of the outcome of the investigation into the Comet crashes, the position of the turbo-prop, so far as this country is concerned, is assured. It did not need disasters to jet aircraft to establish the turbo-prop's role in air transportation. To those interests abroad who may take too much comfort in the fact that the race is not always to the swift, it can be replied that thoroughbreds are difficult to breed and train but they win in the end.

★ ★ ★

THE SMALL FIRM

The British Institute of Management has published as a pamphlet the paper presented by Great Britain at the tenth International Management Congress. This is an examination of the application of modern management techniques in small businesses. It describes briefly eleven techniques, chosen as representative of the various functions of management, and sets out the conditions which make each of them necessary and the optimum conditions of their application. These functions include standardisation, production planning and control, work study, standard costing, joint consultation, etc. The applicability of each function to the small firm is then examined in the light of contributions from a number of the countries which participated in the Congress, and examples from the experiences of actual firms are described.

The general conclusion of the paper is that these techniques can be successfully applied to small firms in a very wide variety of industries. There is, however, an important qualification. The operation of a management technique will tend to increase the number of non-productive employees, and, if this does not lead to a more than corresponding increase of productivity of the direct producers, it will have failed. To ensure success the greatest care is needed in the choice of a new technique and in its adaptation to the needs of the individual firm. The undiscriminating application of modern management methods to the enormous number of small firms could seriously reduce the national productivity. Techniques are no substitute for good management.

The managements of small firms tend to concentrate on shortage of capital as their major disability. The stronger the personality of the owner or manager, the less likely will he be to recognise that personal shortcomings may be at the bottom of his difficulties. Much work has therefore to be done to overcome the resistance to new ideas. The authors of this pamphlet suggest that one way of dealing with this situation would be for those consulted by the small firms on financial matters to consider it part of their functions to support an organisation which assists managements by the provision of appropriate information, by the provision of consultancy services and by the arrangement of facilities for joint activities for research, education and exchange of ideas on methods and performance.

★ ★ ★

SELLING DIESEL ENGINES

The curtailment of rearmament, import restrictions in the principal Commonwealth markets, and foreign competition combined to cause a sharp fall in sales of industrial Diesel engines in 1953, when deliveries had fallen to an average of 171,000 brake horse-power a month, about 15 per cent. less than in 1952. Deliveries of all internal-combustion engines exclusive of those used in aircraft, road vehicles and tractors fell to 311,000 brake horse-power compared with 331,000 brake horse-power in 1952, and 353,000 brake horse-power in 1951. Deliveries for export, which had amounted to £2·0 million a month in 1951 (out of total deliveries of £3·5 million), had fallen to £1·2 million (out of total deliveries of £3·2 million) in 1953. In the first eight months of 1954 there has been a considerable increase in total deliveries which have now regained their 1951 level but this, unfortunately, has been due solely to buoyant home sales: exports have still been running at an average of £1·2 million a month. It is, however, something of an achievement that overseas sales have not been lost to foreign competitors.

German manufacturers have been particularly enterprising both in design and sales methods. They have been very successful with air-cooled, high-speed and supercharged Diesel engines. In the present period of rapid technological development, British Diesel-engine makers are, however, holding their own and are winning orders through improved designs. The number of foreign engines being made on licence in the United Kingdom has also been increasing, and where such engines have distinct advantages there is everything to be said for this practice. British manufacturers, meanwhile, are carrying out basic research on other types of prime movers so that if Diesel engines eventually lose ground to, say, gas-turbines or free-piston compressors, their products will still be in the forefront.

★ ★ ★

BAGHDAD A SUCCESS

Looking at the Baghdad Trade Fair in retrospect, it would seem to have been an unqualified success from all points of view. This was the statement made by Sir Norman Kipping, the Director General of the Federation of British Industries. Almost nothing that was on show remains unsold—even the prefabricated buildings housing the exhibits were the subject of some keen competition among the buyers. Excavators and draglines, buses and cars were sold " over the counter "; there were also several offers for the ice rink complete, as well as for the air-conditioning and refrigerating plant incorporated in it. On the radio side, it is reported that sales have been doubled and the possibility of installing a television service in Iraq is now almost within sight.

In all, during the fortnight that it was open, the Fair was visited by more than 330,000 people. (The total population of Baghdad is only about 550,000.) Trade buyers came from as far away as the Sudan, India and Pakistan in addition to those from Lebanon, Syria, Jordan, Saudi Arabia, Kuwait, Bahrein and Persia. The Arab Chambers of Commerce held their annual meetings during the time the Fair was open and the 300 delegates made a conducted tour. Nor was the younger generation absent, for over 20,000 students and schoolchildren came in specially conducted parties. The local branches of the Institutions of Civil, Electrical and Mechanical Engineers also held meetings which were attended by some 250 members.

The Fair has driven home the potentialities of the markets in the area to all who took part in it. It also allowed many personal contacts to be made. During the next few years, expenditure by Iraq will amount to some £155 millions and forecasts set a total annual income for the neighbouring States of £200 millions in the not very distant future. The potential market is certainly there, and it is no small one, but competition will be keen especially from America, Germany and Russia.

★ ★ ★

TRADE PROMOTION BY THE F.B.I.

British industry, and particularly manufacturers of capital goods, can look forward to the future with confidence: the country has never been more prosperous and prospects have never been better, but opportunities will have to be seized vigorously in the face of increasing competition. This was the keynote of a speech delivered last week by Sir Harry Pilkington, President of the Federation of British Industries, to the London and South Eastern Region of the Federation.

Sir Harry reviewed the part played by the F.B.I. in the promotion of British industrial and commercial interests over a wide field, and expressed the belief that the Federation must do " yet more promotional work for our members." He concluded on a very confident note but urged members to demonstrate their belief " in the urgency of expanding and investing, of improving productivity and of making our salesmanship more competitive, urgent and aggressive." He warned them that Britain was not alone in her prosperity and confidence, and that they would be foolish " to think that our prosperity is a proof that we have gained at the expense of others."

Much of Sir Harry's speech was devoted to the promotional activities of the Federation. He mentioned in particular the recent Bagdad Fair, which he described as an unqualified success and the Federation's most unusual recent venture. He pointed out that Middle East markets were growing fast, in step with rising oil production. For this reason the Bagdad Fair was opportune. Sir Harry rightly said, however, that fairs were no substitute for personal representation in the market. He argued strongly in favour of the man on the spot and considered that " in competitive personal salesmanship we are still underestimating both the quantity and the effectiveness of the German overseas selling effort, and that their attention to detail and their thoroughness is still getting them orders that in our merit we can have."

★ ★ ★

SHIPS AND SHIPPING

The rate at which new orders are being placed with British shipbuilders has shown little increase in recent months. There have even been some more cancellations. The latest, for two ships valued at £1 million, were ordered from a Weir shipbuilder early last year. In general, however,

there is no despondency among British shipbuilders. A high proportion of the British merchant fleet has now reached an age which makes immediate replacement imperative so that the flow of orders for new shipping should not be long delayed.

Shipowners are, however, still very cautious about announcing their future building programmes, and tend to stress the high cost of building. Mr. J. P. Philips, in his recent statement as Chairman, issued with the accounts of the Court Line, warned shipbuilders that when present orders have been executed they may find it difficult to refill their berths owing to the continued increase in costs. He pointed out that although there had been an improvement in freight rates recently, the index of tramp rates in September was 90·6 (average 1952 = 100) which compares with 146·4 in January, 1952. It was still too early also to say whether the recent recovery is likely to continue. While uncertainty about future revenues persists, there is less doubt about the future trend of operating costs—which is likely to be upward. Certainly there has been a fall in bunker costs of about 11 per cent. in the past two years, but port charges, wages, etc., have all increased. The wages of an able seaman are now about £29 10*s*. a month compared with £28 in 1952 and £24 in 1947. Port tonnage dues are now about 2½ times as high as in 1947 and shipbuilding costs have increased by at least 75 per cent. since that date.

Even at the present level of freight rates and building costs, however, there is no doubt that modern efficient ships can make a profit, and the British shipping industry could solve its problems by a bold replacement programme. The scale of investment required is, however, large and there is some danger that the industry may simply fall into decay. As it becomes uneconomic to operate, tonnage is simply sold without being replaced or transferred to other flags, where their operation is governed by less stringent maritime regulations, and where manning costs are appreciably lower. In a recent statement in the House of Commons, the Minister of Transport said that between 1949 and 1953 a total of 144 ships of 500 gross tons and over had been transferred from United Kingdom and Colonial registers to those of Panama, Liberia, Honduras and Costa Rica. The movement is, of course, not entirely away from the British flags; Canadian owners faced with higher operating costs under their own flag have found it convenient to transfer many of their ships to the British register. Movements of this sort, however, can only aggravate the problems facing world shipping by prolonging unduly the life of over-age tonnage and depressing freight rates.

★ ★ ★

MARINE ENGINEERS

Because machinery in ships is becoming more and more complicated there is a danger that there may be a shortage of suitable men to design and run it, Mr. P. L. Jones said in his Presidential Address to the North-East Coast Institution of Engineers and Shipbuilders on October 15. He pointed out that in the last 30 years there had been many improvements in marine engineering, but that each improvement had brought its own complications with it. In the 1920's ship engines were deliberately kept simple, but the call for increased efficiency had led designers to make engines which would compare favourably with any land engine.

But complicated machinery needed careful handling if it were to be used to the best advantage. Although there were many skilled marine engineers, some of the rigours of sea-life were deterrents to recruitment. Not only was there a progressive shortage of suitable men on the ships, but designers were finding that there were not enough young men entering their offices. The design of ships and marine engines was a very complicated matter, because of the varied conditions under which they had to work. Engines had to run at a wide range of speeds, and had to be readily reversible. Vibration was bound to occur at some of the speeds, and there were innumerable ways in which a ship could vibrate. Designing high-temperature steam installations for ships also needed great ability.

The future opened up many new possibilities. Gas turbines had been used at sea, and it was likely that nuclear power would be harnessed for ship-propulsion. The industry needed the best possible men, both to design the ships and to use them.

★ ★ ★

WELDED VERSUS SEAMLESS TUBING

It was announced last week that the Mannesmann and Hoesch organisations in Germany have decided to erect jointly a welded-tube plant in that country. Coming at a time when the Wellington Tube Works, Limited, has announced an offer for sale to the public in this country of part of its ordinary capital, attention has been drawn to the growth of welded tubes in recent years. The Stewarts and Lloyds plant at Corby was described in ENGINEERING in 1952 (vol. 174, page 65). It would be expected that the development of E.R.W. techniques and the ability of welded tubes to meet an increasing range of specifications for tubing would have increased the output of welded tubes throughout the world in recent years. This has indeed occurred. In the United States the output of welded tubes increased from 2·5 million tons in 1946, to 4·8 million tons in 1952, having been as high as 5·6 million tons the year before. In France production increased from 72,000 tons in 1947 to 216,000 tons in 1953. No figures of welded-tube production are published for the United Kingdom.

Has this increase in welded-tube production been at the expense of seamless tubes? Statistics for the world as a whole are not available but figures which are published for the United States, Germany, Japan and France indicate that welded-tube output is increasing more rapidly than that of seamless tubes. So far, however, welded tubes are doing no more than take a larger share of a growing total demand for tubes of both kinds. Thus in the United States the proportion of welded tubes to the total increased from 54 to 63 per cent. between 1946 and 1952; over the same period in Germany welded tubes moved up from 22 to 25 per cent.; in Japan the corresponding figures are 24 and 27 per cent. and in the case of France the proportion between 1947 and 1953 went from 33 to 46 per cent. There is no reason to suppose that the pattern changed for the first three countries in 1953, and it is noticeable that during the American recession both types of tube were affected about equally.

The demand for tubes, both welded and seamless, is sustained to-day mainly by the oil industry (for wells, refinery installations and transportation lines), by pipeline requirements of natural gas, for drainage purposes, pressure tubes for boilers, etc., and a range of mechanical tubes which have a wide variety of applications in industry. So long as these industries, notably the oil industry, remain buoyant and continue to expand, there is an assured demand for both types of tubes, for in all but pipes of very large diameter the engineer has a preference by training and tradition for the seamless variety. It remains to be seen how far a recession in one or more of these key industries would force engineers to specify a cheaper welded tube or pipe where previously it had been the custom to take only seamless supplies. There is already, probably, considerable scope for such a change.

★ ★ ★

AN AUTOMATIC FOUNDRY

The development of automatic core and mould making machines by the Osborn Manufacturing Company of Cleveland, Ohio—mentioned in Weekly Survey, August 13—was taken a step further recently when the installation of a fully automatic "closed-circuit" foundry was completed at the Cleveland plant of the Eberhard Manufacturing Company (of the Eastern Malleable Iron Company). The most striking feature of the new plant is the push-button remote control of core making, pouring and shake-out operations, which reduces manpower requirements from about 40 men, many of them highly skilled, to six men whose main job is to operate the control panel and to lubricate the mechanism. Capital investment is high—some 600,000 dols. for two moulding units—but manpower savings are expected to amount to 300,000 dols. a year and many indirect benefits should result. For example, one of the major problems in United States industry is low output on the first and last days of the week, due to psychological factors; in future, output will be governed almost entirely by the speeds of the machines.

The Eberhard Manufacturing Company's new foundry has an output of one 2½-lb. casting (average weight) per minute. The complete cycle from sand filling to delivery of castings is less than 19 minutes. There are two production lines, each with its own moulding unit, which converge in the pouring station and through a cooling chamber 27 ft. long in which the temperature of the metal is reduced from 2,900 deg. F. to about 800 deg. F. in 13 minutes. The space required by the complete twin production-line unit is 7,200 sq. ft. in a building 15 ft. high except for the sand-delivery plant, which is 68 ft. above the core-making machine. One of the system's outstanding advantages is the degree of flexibility that is preserved. Patterns can be changed in half a minute and switches from one type of casting to another can therefore be made without noticeable effect on the rate of production. The next closed-circuit foundry is being installed at the Pontiac Motor Division of General Motors for the production of cylinder-block castings.

★ ★ ★

CYCLE AND MOTOR CYCLE SHOW

At the Cycle and Motor Cycle Show which opened at Earls Court, London, on November 13, plastics and glass-fibre panelling are in evidence. Mouldings are fitted to one of the scooters, a motor-cycle and as part of the panelling of one three-wheeler. Their lightness and resistance to abrasion and denting would seem to offer a considerable field of use in these applications. Safety and finish have evidently received great attention on both pedal and motor cycles. The size of the show and the variety of the exhibits reflect the health of the industry, which continues to be an excellent dollar-earner. This year there are 185 stands and several foreign makers are exhibiting. Among the British exhibits are two new motor-scooters and one new three-wheeler. The Show closes on November 20.

★ ★ ★

NON-REFLECTING GLASS

In power stations and elsewhere it is a common practice for many instruments to be mounted on a control panel. As a result of the glare from the lighting points, or wrong positioning of the instrument panel in relation to windows, the clear glasses may have a mirroring effect, often making it impossible to read the dials at certain angles.

After a long series of experiments, Pilkington Brothers, Limited, have produced a glass with both surfaces lightly obscured, which successfully mitigates the nuisance of reflection without actually reducing the amount of light transmitted. It is available in thicknesses of 2·6 to 3·2 mm. and upwards, and at present in sizes up to 18 in. by 12 in., and can be obtained toughened if required. Bent glass to approved curves is available as well as flat glass.

The glass is particularly suitable for meter and gauge glasses where the observer is stationed at some distance from the instrument panels and is unable to move into a position to avoid reflections. The glass only functions satisfactorily so long as the dial face of the instrument is reasonably close behind the glass.

TECHNICAL EVIDENCE AT THE COMET INQUIRY

Continued from page 620

On Monday, November 8, the twelfth day of the inquiry into the causes of the two Comet disasters, Mr. Walter Tye, chief technical officer of the Air Registration Board, continued his evidence.

The inquiry, at Church House, Westminster, is being conducted by Lord Cohen, as commissioner, with three assessors: Sir William Scott Farren, technical director of A. V. Roe and Company, Limited, Professor J. W. Duncan, Glasgow University, and Air Commodore A. H. Wheeler, Commandant of the Aircraft and Armament Experimental Establishment.

Sir Lionel Heald, Q.C., appears for the Crown and Sir Hartley Shawcross, Q.C., for the de Havilland Aircraft Company, Limited.

Mr. Tye said that at the end of 1952 it was thought by the Board that the safe life of the Comet would be 10,000 flying hours. When the Farnborough tank tests were later performed, the rapidity with which cracks in the fuselage grew, in some places being almost instantaneous, "came as a surprise."

Mr. Bruno Jablonsky, aeronautical engineer and Associate Fellow of the Royal Aeronautical Society, called to give evidence, said his firm had supplied jigs and tools for the Comet aircraft and he was experienced in many materials used in aircraft production. His view was that the work which had been done by Sir Arnold was valuable and that he and his staff had made an important advance in the study of materials.

Sir Lionel: You agree with Sir Arnold that the immediate cause of the Elba accident was the bursting of the pressure cabin?—Yes, I do.

And that this burst was due to the inherent weakness in the cabin itself?—Yes.

You also agree with Sir Arnold that at any rate one cause of that weakness in the cabin was metal fatigue?

Mr. Jablonsky replied that one of the causes might have been metal fatigue but that the question of metal fatigue was one upon which they probably disagreed. "I think it has not come as early into operation as has been suggested."

FATIGUE IN GLUE LINES?

He thought that there were two contributory causes to which he would like to draw attention—the high rate of climb and the use of adhesives instead of rivets. He knew that adhesives were used in the Dove and Hornet aircraft but he thought that they flew under different conditions from those of the Comet.

Asked if he thought that the cause was connected with the rapid change in temperature being deleterious, he answered, "I think the causes are a certain amount of expansion and contraction in the skin in a rapid climb." He would say that the plastic glue lines were more prone and apt to fatigue than metal.

In answer to Sir Lionel, Mr. Jablonsky said he relied on the existence of a large number of small pieces of wreckage and that these were due to there having been an explosion.

Sir Lionel: If you are going to have an explosion which blows the whole thing into smithereens, how can you at the same time have a fracture of the kind which exists in the pressure cabin ?

Mr. Jablonsky: I would not say it was at the same time. I do not think so.

Sir Lionel: Which happened first? The explosion due to the bursting of the skin, and this took place afterwards?—Yes.

Sir Lionel, speaking of the demonstration with a model of the Comet which Sir Arnold had given before the inquiry with his description of how he thought the break-up of the aircraft had taken place, asked Mr. Jablonsky whether he disagreed with Sir Arnold about that.

He replied: I think it is very difficult to reconstruct the events and the succession of them. I don't think you can completely rely on a model.

Mr. Jablonsky was then asked by Sir Lionel if he could give an explanation different from Sir Arnold's which would account for the places in which the wreckage had been found. He said that he would not be able to give an answer. The only answer he could give was that the drop of the aircraft had disintegrated the parts.

When Sir Lionel Heald suggested that Mr. Jablonsky knew "very little" about the methods of application of adhesives in the manufacture of the Comet, Mr. Jablonsky answered that he had made jigs for the de Havilland company and he knew what the requirements were.

You say it may have been applied too thick or too thin in some places. Do you know?—My opinion is that it is unavoidable.

Mr. Jablonsky agreed that he "suspected" that the Elba, Naples and Calcutta crashes were due to the same cause.

He agreed that his opinion would have to be reconsidered if, by tests, the temperature factor was found to be not as serious as he thought.

He said that the aircraft had been exposed to tropical heat, and the adhesive strength would be reduced by as much as 50 per cent.

Mr. Jablonsky said he did not agree with Sir Lionel's suggestion that his opinion on the behaviour of adhesives at high altitudes must be speculative, because he had no tests to go on.

He agreed that, provided the de Havilland tests had been thoroughly carried out, the results were more likely to be more accurate than his, based on his general knowledge and speculation.

On Tuesday, November 9, Mr. Walter Tye continued his evidence. Referring to manufacturers' cracks, he said, "There was no lack of appreciation between the design and inspection staff at de Havillands about cracks in aircraft fuselages and to taking proper precautions to find them."

Mr. Shaw, appearing for some relatives, questioned Mr. Tye about whether the treatment of the cracks in the Comet in the Elba crash was considered safe.

Mr. Tye said that at that time he would have considered them safe cracks, having been located by holes. Even in the case of the aeroplane, after having gone through repeated loading tests there was no sign of any appreciable lengthening of any of the cracks—certainly not any danger of those which had been located.

Mr. Shaw: Had that hole not run to a rivet, the answer might have been different?—Given a very long time I presume it must have been different.

Mr. Tye was asked by Lord Cohen (chairman) whether he thought that the Comet Yoke Uncle (which was used for tank tests at the Royal Aircraft Establishment at Farnborough) and the Comet Yoke Peter (the one which crashed off Elba) failed for the same reason or for a different reason.

Mr. Tye answered that it was clear from the tank test that it must have been fatigue which caused the disruption in the aircraft in the tank. He added, "I am not so confident, although I have no alternative explanation to offer to support the view, that the Elba accident was due to fatigue."

The chairman: If you had had the cracks particularly in your mind, would you have been less likely to rule out the question of fatigue?

Mr. Tye: I think that probably, having regard to what we believed to be the probable safe life of the structure which I have said previously was quite clearly of the order of 10,000 flying hours, which is a large margin of safety, I think that with the additional knowledge of manufacturing cracks we should still take the view we had adequate cover in the overall margin.

Mr. Tye said that after the accident at Calcutta, where a Comet broke up in a storm, one of the recommendations made was that the feel of the control system should be re-examined.

The Air Registration Board, said Mr. Tye, was entirely satisfied with the acceptance of the feel of the control system but felt it would like another opinion and therefore a Comet was flown at the experimental station at Boscombe Down.

TESTING TO DESTRUCTION AND SAFE CRACKS

When his attention was called to the suggestion that a new aircraft should be tested to destruction in future, Mr. Tye said, "Yes for the immediate future. While we are finding things out I think it is absolutely essential for aircraft to be tested like Yoke Uncle was tested at Farnborough, but I hope, thinking a little ahead, that it will not be a continuing necessity. "Ideally one would like to get to a state where an aircraft can crack safely."

Mr. Tye was asked about the system of inspecting aircraft by inspectors and, in particular, about the inspection of a defect near a "cut-out" in the skin of the aircraft. He said he did not think any change in the inspection system was possible or even desirable.

"It is almost inevitable that under the system there will be occasional errors made," he said.

The chairman suggested that the question which was being put to Mr. Tye was: "Ought not the instructions to the inspectors the of de Havilland company be to pay attention to sections of the skin near 'cut-outs'?"

Mr. Tye replied that he believed the inspectors were very well aware of the importance of paying attention to the "cut-out" sections.

Mr. Tye was asked about a report from the de Havilland designer, Mr. Bishop, that two years had been saved in the production of the Comet and whether this had any effect on the safety of the aircraft.

He replied: I think perhaps Mr. Bishop was not writing for this audience. I think most designers would claim they had saved two years by the same process.

When asked if he thought a larger staff at the Air Registration Board would be an additional safeguard, Mr. Tye said he did not think any substantial change in the present position would make any material difference.

Mr. Tye told Mr. Rodger Winn (representing the de Havilland Aircraft Company) that his Board had been on friendly and co-operative terms with the de Havilland design department throughout the whole of the development of the Comet, and that many of them were on "Christian-name terms."

It was not until about 1952 that the members of the staff of the Air Registration Board began to think of fatigue as a serious matter for pressure cabins.

AIRWORTHINESS MISCONCEPTION

Mr. Winn: The impression has undoubtedly got abroad that the American airworthiness authorities in some way or other turned down the Comet III: ruled that it was unsatisfactory in some respect having regard to their requirements or proposed requirements. Is there any foundation for any such impression?

Mr. Tye: None at all.

Mr. L. G. Scarman (for the Air Registration Board): You expressed less confidence in the fatigue origin theory for the disruption of the pressure cabin than some previous witnesses, but you do not have any alternative theory that you can put before the court?

Mr. Tye replied that he had no alternative.

Mr. Scarman then asked: It is fair to say that any less confidence which you may have in the fatigue theory is not such as would lead you to suggest that the fatigue theory can be ruled out?—By no means. I think it is a possible theory. The question in my mind is how probable a theory.

Mr. Tye said that on the day of the Naples disaster, Lord Brabazon, Chairman of his Board, sent a letter to the Minister of Transport and Civil Aviation, saying, "I am of the opinion that in spite of all its efforts the Board cannot disregard the real possibility that there is some factor influencing the airworthiness of Comet aircraft which the most diligent investigations have failed to discover.

"Until such time as a satisfactory application is available the Board recommends that Comet certificates of airworthiness should be withdrawn."

Mr. Tye said he did not think a serious view was taken of manufacturing cracks after Elba, nor did he know of any manufacturing crack spreading beyond the locating hole in any Comet until Yoke Uncle, which was submitted to the tank test and in which he thought there was one such hole.

Mr. Scarman: That spread, but not catastrophically?—It spread in a safe manner.

Mr. Scarman read from a letter, written in December, 1949, from an official of the Royal Aircraft Establishment to an official of the Air Registration Board which gave results of tests done on pressure cylinders at the Establishment to see whether the development of cracks in a pressure cabin would lead to disastrous failure. Mr. Tye said that at that time it had seemed an encouraging test for assuming that quite serious cracks could be present but would not necessarily develop.

Referring to the points of stress in Comets, Mr. Tye said: "I feel that perhaps an undue amount of weight has been attached to the extreme-edge test which one would not expect to be critical, and so far as the tests were concerned, there is no evidence that cracks started from the edge. They started from the rivet holes, I understand."

TESTS NOT CALCULATION

He thought they would need fatigue tests and repeated loading tests to get the truth of the stresses, rather than calculation.

On Wednesday, November 10, Professor Alfred John Murphy, Professor of Industrial Metallurgy at the University of Birmingham, told the court that he was appearing in an independent capacity and was not personally associated with the de Havilland company.

He said that the combination of strength and lightness was a very important factor in the development of aircraft and he thought it true to say that the development of aluminium alloys had been a very important factor in making it possible to achieve

the advances in aviation that had taken place in the last 20 or 30 years.

Sir Lionel Heald, Q.C., for the Crown: I understand that members of the public have expressed some anxiety that such thin metal material could be safe when used in aircraft at great heights.

The Professor gave to the court several details on the technical nature of aluminium alloys and, when shown two pieces of metal stated to have been taken from the crashed aircraft said: "Tests of these confirm that the material amply satisfied the requirements of the relevant specifications." The material had been tested and found to be "perfectly sound."

Professor Murphy said he had no reason to differ from the Royal Aircraft Establishment conclusion on fatigue having occurred in the Comet.

Giving his views on the possible causes for the Comet structure break-up earlier than its calculated flying life of 10,000 hours, Professor Murphy said that he agreed "in broad terms" with the conclusion reached from the Farnborough tests about the cause of the accident.

He said: "We know what the general level of stress in the metal was and we have evidence that a stress raiser was present in the form of a countersunk hole to cause fatigue in the point where we could see signs of fatigue."

Robert Henry Basil Harper, Chief Structural Engineer to the de Havilland Aircraft Company, Limited, since 1949, and a member of the Joint Airworthiness Committee and of the Airworthiness Co-ordinating Requirements Committee, said that he was responsible for tests of a structural nature. Among the aircraft he had dealt with at the de Havilland company were the Mosquito, Hornet, Sea Hornet, Vampire, Venom, Sea Venom, the D.H. 110, the Dove, Heron and Comet.

WING FATIGUE TESTS

It was in 1946 really for the first time that the problem of fatigue was considered, in connection with tests on the Dove. As a result of those tests, in 1949 there was a discussion at the Air Registration Board and it was decided to test the Comet wing under repeated loads.

In 1949 a certain American aircraft had an accident due to wing fatigue; in September, 1951, a similar thing happened to a British aircraft; and in October, 1951, a Dove broke up in Australia due to fatigue. As a result, the whole industry became conscious of the danger of fatigue in aircraft wings.

He said that a meeting was summoned in 1951 as the result of a letter written by Mr. Walker, of the Royal Aircraft Establishment, to the Director of Research and Development at the Ministry of Supply.

In the letter it was stated: "The fatigue situation gives rise to some concern. We estimate that the original design would have a life between one-fortieth and one-twentieth of what we normally require and usually obtain. Three joints are known to be seriously under strength in fatigue, but not, so far as can be judged, beyond remedial action.

"Two have in fact been modified by the firm and are probably now completely satisfactory, but the third modification has still to be done. Confirmatory tests on specimens of these three joints will, however, be necessary and should preferably be made at R.A.E. Action on this is already proceeding."

Mr. Harper said that, in 1953, following information received on pressure-cabin fatigue, they began to consider the Comet fuselage specifically in terms of fatigue life.

In June, 1953, proposals were put by the Air Registration Board under requirements for pressure cabins. They required an ultimate factor of twice working load and repeated operations of 1¼ times working pressure. In fact, the de Havilland company carried out repeated load tests on the fuselage nose and centre section twice at working pressure.

Mr. Harper said: "We had no idea of any danger of fatigue. We were concerned with leakage and the fact that it was a pressure container and we wanted it to continue to be so. We were quite confident about the general design."

Continuing his evidence on Thursday, Mr. Harper said that his firm started testing Comets in January, 1946.

"MOST TESTED CIVIL AIRCRAFT"

"In the whole of the Comet project we have carried out 500 test investigations. This has involved some thousands of tests of all the basic structure of the Comet. Before the Comet Yoke Uncle went to Farnborough for the test in the tank it was the most tested civil aeroplane in this country."

He said that pressure tests were carried out on the nose section and the centre section of the Comet. On both sections tests at a pressure of 16¼ lb. per square inch had been carried out.

When asked by the chairman for the extent of co-operation between the de Havilland company and the Royal Aircraft Establishment, Mr. Harper said that the original test programme which the company laid down as suitable to cover the Comet project was examined by Farnborough (R.A.E.).

They approved the programme with one exception —instead of proof-testing a wing and then using that wing for an aircraft the Royal Aircraft Establishment thought it should be tested to destruction and the company agreed to supply a wing for the destruction test.

When the fatigue situation was being discussed they had many consultations and, from his personal interest of structural testing, he thought the co-operation was ample on both sides.

Mr. M. A. L. Cripps, representing the Ministry of Supply: The de Havilland tests were partly to satisfy de Havilland that the aircraft was of satisfactory design and would fulfil the requirements of customers? Not only the requirements of customers but the requirements of the Air Registration Board.

Questioned by Mr. L. G. Scarman, for the Air Registration Board, about the Board's requirements for airworthiness, Mr. Harper said there had always been complete understanding and co-operation between the de Havilland company and the Air Registration Board.

Mr. Scarman: When new ideas have been in the mind of the Air Registration Board these ideas have been passed on to you and your company.—Yes.

Mr. J. M. Shaw referred to the Farnborough test reports which said the stress in the area of a window cut-out was 70 per cent. of the ultimate and that the Comet in the tank test, Yoke Uncle, failed at 9,000 hours. He asked, if the conclusion of 70 per cent. was right, would it not be considered that a Comet was in danger after 3,000 hours?

Mr. Harper said he would not consider an aircraft was in danger after 3,000 hours but he did not accept the figure of 70 per cent. He thought it was about 50 per cent. or possibly a little more. In other words, he considered his original calculations were about right.

Mr. Shaw: Then there must have been something about Yoke Peter which caused a stress and the failure after 3,000 hours?—It is very difficult to try and define limits to problems of this type.

Mr. Harper added: "In a complex structure there might be locked-up stresses which are not present in the specimen and I feel that investigations have shown that we must work on lower stresses around cut-outs."

Mr. Shaw: What was causing these locked-up stresses in Yoke Peter?—I would be prepared to accept the evidence of fatigue at a bolt hole and that could have caused a locked-up stress. I would have taken a bolt hole into my calculations from a static viewpoint, but the only way is to do fatigue tests. There is no direct method of approach mathematically to get the answer to these problems.

Mr. Harper said that in considering a future aircraft, besides considering it from a static viewpoint there would have to be a lot more fatigue testing around the windows and doors.

Mr. Harper said that he did not think that the rivet's being near the edge had any particular effect and could not be one of the factors that started fatigue.

UNREPORTED CRACK

Mr. Shaw: We know that the manufacturing crack in Yoke Peter was not the subject of a concession note. It means it had been discovered by a workman in course of manufacture and not reported?—Yes.

Therefore, whatever the system of investigation may be to check what workmen do, it does not discover all cracks that are made in the area of these windows?—It may appear so. I would prefer that you would ask me questions as to the effects of cracks rather than as to inspection procedure.

As a result of that, it is clear that there may be hair-cracks in the vicinity that were not even detected by the workmen with the naked eye and would therefore not be seen by the inspectors in the course of their inspection?—The whole of this area should be inspected with a magnifying glass.

The chairman: A crack was discovered and located and there may have been others which were not located?—Yes.

When Mr Shaw said that a crack on the skin was big enough for a workman to see with the naked eye, yet it was not reported, the chairman said it was not a question for Mr. Harper and it might have been that an inspector was not doing his duty properly.

Mr. Shaw: It showed at least one crack which was visible to the naked eye but which was not reported? —Yes.

Mr. Shaw: We know that some of the manufacturing cracks which had been detected and located propagated?—Yes.

If we have a crack which has not been located, it would propagate more readily?—Yes.

And would therefore be a very great danger as a source of fatigue, because it would propagate more rapidly?—If it was in the area of great stress, and one must remember that some parts are more highly stressed than others and in some parts it would be dangerous and in some parts it would not.

After the luncheon adjournment Mr. Harper was questioned by Mr. R. A. MacCrindle, for the British Airline Pilots' Association, who asked if, in the event of the theoretical calculations being inconsistent with the test results, they would have "thought again" before saying the aircraft was structurally sound.

Mr. Harper replied: "We thought it was sound because we had demonstrated with tests that it would take twice the working pressure."

He added that he would have been surprised had the calculations proved too far "adrift" (relating to static strength). Had there been a large discrepancy he would certainly have wanted to resolve it before committing the aircraft to flight.

Asked if, in the calculations, he allowed for the raised stress-concentration factor around the rivet hole, Mr. Harper said, "You take that into account by removing the area of the rivet hole. We worked on a peak average stress in the vicinity of the window frame, which made allowance for the fact that rivets were there. We took a reduced area of section."

Replying to further questions on stresses, he said, "If, by calculations, we had arrived at a stress of 40,000 lb. per square inch, and by tests the results suggested that the stress was nearer 26,000, the value we took statically, I should accept the test figures. If I was thinking fatigue-wise I would have done fatigue tests. I would probably have tackled it from a further aspect, and probably have done a different set of calculations to see what they gave."

In answer to further questions on manufacturing cracks, Mr. Harper said that they could not be avoided entirely. Not all manufacturing cracks were due to methods of tooling. They could be due to some one dropping a chisel on the floor, or something like that. If a manufacturing defect was brought to his notice, he took the appropriate action.

WINDOWS

In reply to another question, Mr. Harper explained that in the Comet III the windows were oval, instead of square, because it enabled them to save weight on the structure as a whole.

Asked by Mr. T. H. Tilling, for the Navigators' and Engineer Officers' Association, whether they allowed for gusts in testing the nose portion, Mr. Harper replied: "It is impossible to reproduce everything that happens in flight. Everything is a compromise. One could not represent precisely. We do not know precisely. We applied pressure greater than the working pressure, in our nose pressure tests."

Mr. Ronald Eric Bishop, Chief Designer of the de Havilland company, said he was responsible for the designs of many aircraft including the Comets I, II and III.

Asked what he thought about suggestions that the company had been in too much of a hurry in developing the Comet, Mr. Bishop said, "I do not think so. We most certainly did not rush the thing into production. The reason for production at the same time as design was to enable the production people to get ahead without waiting for the prototype. Before Elba, the Comets had flown about 25,000 hours. The total flying by the time of the Naples accident was 34,567 hours."

Sir Lionel referred to an article Mr. Bishop wrote in "The Aeroplane" in 1952, and Mr. Bishop said he now entirely agreed with what he had written then. Reference was made to Redux, a material used as an adhesive of aircraft parts, and asked about this Mr. Bishop said, "We used it in the Hornet and we had considerable experience of it in the Dove, where it is used for similar applications to the Comet. It is used all over the world, and to my knowledge we have certainly had no reports of trouble."

Sir Lionel: What do you say to the suggestion of the possibility of Redux being a contributory cause of the failure of the pressure cabin in the Elba accident?—I see no reason, no evidence, for that, neither from the many tests we have done, nor from the wreckage. I feel entirely satisfied in continuing to use it.

Sir Lionel: In 1952, did you attach importance to the statement you made of the gravity of the problem of pressurisation?—I thought it was one of our biggest problems because we were very alive to the consequences of a failure. It was obvious that if a pressure cabin failed, or if a window blew out at 40,000 feet, it was a serious situation, and much thought and testing was done with the object of making sure that the cabin was safe. We obviously missed the main line.

Sir Lionel: You say in your article, "We treated the

windows as a special case, and tested them to a safety factor of ten (82 lb. per square inch)." Does that show the particular attention you thought it necessary to direct to this cut-out factor we have heard so much about?—Yes. There had been cases of windows blowing out in civil airliners, and pressurisation failures had taken place.

Mr. Bishop added that these tests referred only to the transparencies themselves.

Sir Lionel asked Mr. Bishop what he could say about discussions in 1952, about repeated loadings of the fuselage.

Mr. Bishop: There were draft proposals from the Air Registration Board, and also on military aircraft, which were submitted to the various co-ordinating committees for discussion. We took note of that fact and we knew repeated loading tests were being done on the Apollo fuselage and one or two others, and we felt it would be wise to submit our nose specimen to a large number of repeated loadings to make sure it was all right. That was in accordance with the general policy in the company.

"We had done 2,000 loadings on the test nose considerably earlier, and we felt that that covered the early stages of the flying of the aeroplane, and we would need to do a lot more repeated loadings to keep ahead of the life of the aeroplane. 18,000 loadings on that test nose, we felt, were so far in advance of the aeroplane, that even with a very large factor we had no need to worry. We were content to keep ahead of the hours the aeroplane had flown. We had discussions with B.O.A.C. and we knew replacements would have to be made to the wings of the Mark I Comet."

SIMILARITY OF CIRCUMSTANCES OF CRASHES

Sir Lionel: If we go to the time after the second accident, did you then consider very seriously what view you could reach as regards the cause of the accident?—We did not know the cause of the accident. We knew both accidents had happened under very similar circumstances, both about half an hour after take-off, and both about the top of the climb. Both apparently had been on fire in the air. There were certain similarities.

Discussing further tests on the pressure cabin, Mr. Bishop said that he had been in favour of putting 16½ lb. per square inch pressure on the oldest fuselage available, but it was decided, largely on Dr. Walker's instigation, that it would be better to do a repeated-loading test, putting on wing loads and normal fuselage pressurisation. In the light of what happened, that had been a very wise decision.

He agreed that the whole resources of the Royal Aircraft Establishment were brought to bear on the problem, and expressed his appreciation of all that had been done.

Sir Lionel: After the Elba accident, and before the Naples accident, had there been any suggestion, before the wreckage was found, that fatigue in the fuselage was the cause of the failure?—We had considered the possibility but in the light of our tests we felt it was ruled out.

Sir Lionel: When you came to discuss the tests decided upon after the Naples accident, were you then directing your mind to questions of fatigue?—I would say, not much more; a little more perhaps than after the Elba accident. Everybody felt it was much more probable that any bursting of the pressure cabin would have been due to deterioration of the cabin structure through such things as heavy landings or damage by such things as steps maintenance. We were looking for that sort of thing much more.

Referring to the tank tests, Mr. Bishop said, "We thought we were covered by the tests we had done, and it was a great surprise to me personally when the fuselage blew up in the tank at 9,000 hours. We thought we had a much longer life than that."

It was generally regarded in the aircraft industry, among designers and people who certify aircraft, that provided the structure had been demonstrated capable of taking twice the ultimate static load there was no real worry. The de Havilland company had insisted on additional tests because of the height at which the Comet was flying.

Continuing his evidence at the inquiry on Friday, Mr. R. E. Bishop, designer of Comet jet airliners Marks I, II and III, said he agreed with the Farnborough report where it was said that the Elba accident was caused by structural failure of the pressure cabin brought about by fatigue.

Sir Lionel Heald observing that there had been evidence from several witnesses all of whom had agreed that the difficulties in the Comet could be dealt with, asked Mr. Bishop if he would like to comment on that aspect.

"I feel that now the problem is appreciated there will be no great difficulty in dealing with it," he replied. "I do not think anybody need have any fears that we cannot put this right in the future, but it is only recently that aircraft designers realised that there was a problem of fatigue in pressure cabins."

On the methods of dealing with the question they did not entirely agree with the view put forward by Sir Arnold Hall. Mr. Bishop said he believed that a large number of specimens would have to be made, but before that they would have to establish a detailed design technique—it had already been started—which would mean a very large number of small tests. In those tests strain gauges would be used wherever possible, but he stressed that they were "only a tool and not an answer to everything," and often could not be used in the most vital places.

"Finally, I believe we shall have to finish up, for a few years anyway, with a major tank test with the wings on the fuselage," said Mr. Bishop.

Mr. J. M. Shaw asked about stresses round the windows, and Mr. Bishop said Sir Arnold Hall gave a stress level at 70 per cent. around the edge but that was not the general stress level. He thought it was true to say that the closest strain gauge to the edge was only 0·2 of an inch away from the edge and that showed a very much lower reading than 70 per cent.

Mr. Shaw: I asked Mr. Harper if when he had a general level of not more than 50 per cent., did that mean he thought there was no point at all where the stresses exceeded 50 per cent. His answer was "Obviously stresses round the bolt holes and rivets would exceed 50 per cent. They would theoretically exceed 100 per cent." Does that mean that when you were planning you knew there were points in this area where stresses might reach 100 per cent.

Mr. Bishop: No. We did these calculations to design the test piece. We knew that any rivet hole has the effect of raising the stress. I think Mr. Harper meant that if there is an area of stress of 50 per cent. and on top of that there are local stress raisers such as rivets, and if the structure stands twice the load as it did, then quite obviously there must have been stresses theoretically of 100 per cent. or over. In putting the load on, the material would in fact have got out of the way and they did not fail.

Mr. Shaw: I am not quite following. What I am trying to get at here is to what extent there is new knowledge. You knew at that time you would get points where the stresses would be very high.

Mr. Bishop: I think it is common knowledge and has been for some time that rivet holes and bolt holes do increase the stress very locally for a small distance around the rivets. At that time we were not considering fatigue in the pressure cabin.

Mr. Shaw: Did you not know that points of this type could cause fatigue?—We did not consider fatigue. We relied on the fact that if the specimen would take twice the load, that would cover.

Replying to questions by the chairman and Mr. Shaw, Mr. Bishop said he relied on tests to tell him that what he had designed had solved the fatigue problem.

Pointing out that Mr. Bishop had expressed confidence that the problems arising from the disasters would not prevent the Comets flying again provided modifications were carried out, Mr. MacCrindle asked if he were now prepared to increase the thickness of the gauge of the metal part.

Mr. Bishop: Yes. We are and it is even more important to reduce local concentrations of strain. We shall increase the gauge of the fuselage skin but we shall have to reduce the local concentrations as well.

Mr. Tilling asked about the tests that were done on the nose section of the cabin and the centre section of the fuselage.

Mr. Bishop said that they were the main big test pieces but there were innumerable smaller test pieces as well.

"SCATTER"

Mr. Tilling: What was you attitude to "scatter" at the time these tests were made? Did you treat the nose section as the test of one specimen or did you in some way bring in the individual tests of small sections and get an average?—No. We were still thinking that if that specimen stood twice the required factor, that is all that was necessary.

Mr. Tilling: Does that mean you had knowledge of the scatter problem in those days but thought some other test would take care of it?—I doubt if there was any knowledge of any scatter of fatigue on fuselage pressure cabins. There was very little knowledge of fatigue in wings or anywhere else at that time.

Referring to the tributes which had been paid to Mr. Bishop over the design of the Comet, Mr. Winn asked: Would you desire to say here publicly that you were not then designing with fatigue trouble in mind?—Yes, I would say that.

Are you anxious that all concerned should know that as a result of the general increase in relevant knowledge and very largely as a result of all that Farnborough have so brilliantly done, you now see you have a different problem to deal with in the future?—Yes, but I am quite confident that it can be dealt with.

Mr. Bruno Jablonsky in a statement to the court on the question of adhesives said the de Havilland tests had given full marks to the adhesive as such, but they did not prove how the adhesive would have behaved if simultaneous loads had been applied and if expansion and contraction had had any chance to come into operation under normal stress loading in the fuselage.

The tests, he said, were carried out with small pieces of 9-in. length and they were tested free to expand or contract without being anchored and without any loads being applied during the temperature tests, as would have occurred in the real flight. Those tests therefore were a completely unsatisfactory foundation for the application of the method to quantity production of large complex structures.

He said, "As the test pieces were, of course, made and treated under laboratory conditions it is not reasonable in practical terms to assume that the thousands of feet of glue joints involved in actual production would have the same consistencey.

"My fears that the tests at Farnborough could not show or educate us on the question of such failures as I suspect have taken place have been proved by the tests which have been carried out since and the absence of any comprehensive evidence in respect of reliability of glue lines.

RAPID CHANGES IN CONDITIONS

"We are concerned with a new method of production. The fact that glued joints have been used for the last year or two on other well-known aircraft is no proof that this technique is already foolproof and that it can be applied in a reliable manner in such an aircraft as the Comet which is flying under very adverse atmospheric conditions with 40 to 50 passengers within 20 to 30 minutes from hot or even tropical conditions to the severest Arctic conditions.

"None of the aircraft of which I know, and which have been mentioned as using glued-up parts, are using these to my knowledge on major structural members to the extent to which they have been used on the Comet."

While cracks due to metal fatigue, or other causes were noticeable and could be traced, defective glue lines were not visible and even if they were not hidden it would not be an easy matter to inspect glue lines as with riveted or welded joints.

A reliable inspection method was a fundamental necessity for the application of glue on major structural parts. Without such inspection glued joints should not be relied upon without mechanical safeguards.

Mr. Jablonsky then referred to the elongation of material found in various test specimens and said that one could build up an equally strong, if not stronger, case to show that fatigue in glue lines and splitting of the skin must have occurred first. He was confident that if they opened up long stretches of the glue lines which had remained intact, evidence of uneven adhesion would be found.

He said: "It is obvious that once a slight split has started it will travel fast causing strains and stresses in adjacent parts of the structure until it hits other weak parts of the fuselage such as parts which, due to metal fatigue, only require a comparatively small additional load to cause complete bursting.

He added: "I am not opposed in principle to the use of the gluing method and I am fully aware of the great advantages which can be gained. I hope my criticism will not deter anybody who has already gained enough experience in using this method on various parts of the aircraft. The exclusion which I would strongly advocate for the time being, until more experience is gained and inspection methods are foolproof, is a pressurised aircraft fuselage."

In conclusion Mr. Jablonsky said latent defects in glue lines might be produced by manufacturing imperfections or by temperatures in tropical climates having regard to the normal loads on aircraft structures.

Changes in temperature produced differential contraction of the skin relative to the stringers on the upward flight and expansion on the downward flight, producing stresses leading to the loosening and rupture of the glue lines. Additional stresses in parts of the fuselage might lead directly to failure of the structure.

Sir Lionel, announcing that he had called all his evidence, made a short statement in which he said that he was glad to be able to inform the court of certain practical steps which the Air Registration Board proposed to take, with the minister's approval, as the result of the consideration they had been giving to the matter for several months past.

"In the first place the Board has already indicated its intention that complete cabins of pressurised aircraft be submitted to tank tests similar to those used

at Farnborough until knowledge of the fatigue problem has become much more exact," he said.

"Before the certification of certain prototypes can be contemplated by the Board, therefore, provision will now be required for fatigue testing of entire components and in the Board's view at least two airframes of each prototype will have to be made available, one for static testing and the other for fatigue testing.

"Secondly, as you have heard, the whole of the country's technical resources can be made available to the Board. In view, however, of the difficult problems facing aircraft designers and the Board at the present time, careful consideration has been given to the advantages which could be derived from the inclusion on the council of the Board of one or more additional members specially selected for their eminence in the scientific field. It is proposed to take action on these lines.

"Various other measures are under consideration but I do not think it would be of assistance to the court to go into them in detail. I might however mention two points. The first is a purely practical matter—the value of test flights in the shape of extensive flying on proposed routes with fully instrumented aircraft, especially in relation to engines of which there is no background of experience.

FATIGUE IN LIGHT ALLOYS

"The second point is concerned with research. As you have heard, the Board has been concerned for some time about the structural integrity of modern high-performance pressurised transport aircraft. The importance of research on fatigue in aircraft has also become increasingly apparent in recent years and much valuable work has been done on this by the Air Registration Board, in the industry, and in the Ministry of Supply. In particular, research on the problem of fatigue in high-grade light alloys has been sponsored for a long time by the Ministry of Supply and work on the programme has been intensified during the past two or three years. The subject is continuously before the appropriate committees of the Inter-Service Metallurgical Research Council. Although the subject is a difficult one and rapid results cannot be expected it is fully recognised that the best brains and resources ought to be directed to it and the Ministry of Supply has agreed to give the fullest co-operation to this work."

Mr. Rodger Winn, appearing for the de Havilland company, called Mr. Harry Povey, a director of the company, who is responsible for the organisation of the aircraft factories.

He was asked by Mr. Winn, "In the case of Yoke Peter we have one concession in evidence of three manufacturing cracks. There was another crack in the skin near the rear A.D.F. hatch. That was not the subject of a concession. What can you say about that?"

Mr. Povey: My personal opinion is that at the time the inspection was made there was no crack but, during the assembly, some incidental damage must have happened. Obviously the workman had seen the crack, because it had been drilled out. I think he probably omitted to call the attention of his supervisor or the inspector to it and the assembly was closed, so the inspector would not have an opportunity of inspecting that portion of the skin again.

Mr. Povey, replying to further questions, said it should not have been necessary for the workman to do any work on the cut-out in the final stage of his task, but there might have been some distortion of the skin and it might be that while putting that right he accidentally split the skin. In cases like that they did, of course, depend on the integrity of the workman to a great extent, and they had discussed ways and means of trying to bring to the notice of their employees the importance of disclosing the smallest defect they found or made.

Turning to departures from drawings relating to the spacing of certain rivets round the hatch of Yoke Peter, Mr. Winn asked: You have found that the loss of dimension in YP does vary at different rivet holes from minus 0·01 in. to as much as 0·07 in.?—That is true.

Do you think from your experience that a difference of that degree would seriously weaken the rivets in that position on the skin?—That is quite a difficult question for me to answer. Obviously we have had concessions.

Mr. Povey said that the de Havilland company employed 843 inspectors in their four factories which amounted to 10 per cent. of the production, tool manufacture and experimental workers. The supervising inspector was responsible directly to the managing director. Thus he was quite independent and was not subject to influence from either the design or production sides.

The inquiry adjourned until Wednesday, November 17.

To be continued

PERSONAL

SIR GRAHAM HAYMAN has been elected deputy president of the Federation of British Industries, 21 Tothill-street, London, S.W.1.

MR. FORBES JACKSON, M.I.E.E., M.I.Mech.E., who joined the service of the London County Council in 1933 and became deputy chief engineer in 1952, retired on November 7, on reaching the age of 65 years.

Two Royal Medals have been awarded by the Royal Society, Burlington House, London, W.1, one to SIR JOHN COCKCROFT, K.C.B., C.B.E., F.R.S., for his work on nuclear and atomic physics, and the other to PROFESSOR H. A. KREBS, F.R.S., for his contributions to biochemistry.

The President and Council of the Royal Society, have also awarded the Copley Medal to SIR EDMUND WHITTAKER, F.R.S., for his contributions to pure and applied mathematics and to theoretical physics; the Rumford Medal to DR. C. R. BURCH, F.R.S., for his contributions to the technique for the production of high vacua and to the development of the reflecting microscope; the Davy Medal to DR. J. W. COOK, F.R.S., for his fundamental investigations in organic chemistry; and the Hughes Medal to MR. M. RYLE, F.R.S., for his experimental researches on radio astronomy.

MR. C. A. WINN, M.I.N.A., joint managing director of C. H. Bailey Ltd., Cardiff, has been elected President for the coming year of the Shipbuilding Employers' Federation, in succession to MR. T. EUSTACE SMITH, T.D., M.I.N.A., managing director of Smith's Dock Co. Ltd., North Shields and South Bank-on-Tees. MR. HORACE WILLSON, M.I.N.A., M.I.E.S., chairman and managing director of Wm. Hamilton & Co. Ltd., Port Glasgow, becomes senior vice-president, and MR. E. J. HUNTER, M.I.N.A., M.I.Mar.E., a director of Swan, Hunter, and Wigham Richardson Ltd., and MR. G. C. PARKER, M.I.N.A., M.I.E.S., managing director of the Caledon Shipbuilding and Engineering Co. Ltd., Dundee, have also been elected vice-presidents. MR. HENRY ROBB, M.I.N.A., M.I.E.S., chairman and managing director of Henry Robb Ltd., Leith, has been elected chairman of the Conference and Works Board, and MR. HOWARD JOHNSON, M.I.N.A., M.I.E.C., managing director of Hall, Russell & Co. Ltd., Aberdeen, vice chairman of this Board.

MR. E. GREEN, M.Sc., having reached the normal retiring age, has relinquished, with effect from November 1, his position as head of the transmitter advanced development group of Marconi's Wireless Telegraph Co. Ltd. He is, however, continuing his work for the company on a full-time basis as a consultant engineer. MR. V. J. COOPER, B.Sc., A.C.G.I., M.I.E.E., M.Brit.I.R.E., has been appointed chief engineer, advanced development, with effect from November 1.

MAJOR J. W. RICHARDSON, until recently senior Army Assistant on the staff of the Director of Military Aircraft (Research and Development) at the Ministry of Supply has now been appointed manager of the London office of Westland Aircraft Ltd., Yeovil, Somerset.

MR. H. J. STILES, manager of the de Havilland Engine Co.'s northern unit at Lostock, is joining de Havilland Propellers Ltd., Lostock, as sub-contracts manager on December 1.

MR. H. M. MORGAN, works engineer to the Cargo Fleet Iron Co. Ltd., Middlesbrough, has been installed President of the Cleveland Institution of Engineers, in succession to MR. F. KENNEDY.

MR. R. C. MOSEDALE, senior technical assistant to the district engineer, British Railways, North-East Region, Leeds, has retired, after more than 40 years of railway service.

MR. A. W. DEAN has joined A.K. Fans Ltd., 20 Upper Park-road, London, N.W.3, in an executive position. The firm also announce that they have now taken over further factory space at 352 Goswell-road, London, E.C.1.

MR. R. S. D. BAGNALL has been released, at his own request, from his appointment as home sales director to the Brush Electrical Engineering Co. Ltd. MR. L. C. W. TURNER, sales director, has taken over Mr. Bagnall's duties and responsibilities.

MR. J. G. JACKSON has been appointed manager of the Glasgow branch of Enfield Cables Ltd., Victoria House, Southampton-row, London, W.C.1. MR. F. R. MACKENZIE has been appointed manager of the firm's Newcastle branch, MR. W. F. LAWRENCE, manager of the Southampton branch, and MR. H. DENNIS, A.M.I.E.E., manager of the Manchester branch.

MR. W. LATTA, sales manager, Rhodes, Brydon and Youatt Ltd., Waterloo Engineering Works, Gorsey Mount-street, Stockport, Cheshire, has been elected a director of the company.

MR. R. T. SPOONER has become a sales representative covering the Midlands area, on the staff of Head, Wrightson & Co. Ltd., Thornaby-on-Tees.

MR. F. P. O. STRANGE has been appointed sales manager and MR. C. D. WENHAM, contracts manager, of Teddington Industrial Equipment Ltd., Windmill-road, Sunbury-on-Thames, Middlesex.

MR. J. DEAN, secretary of A.P.V.-Paramount Ltd., the foundry subsidiary company of the A.P.V. Co. Ltd., at Crawley, Sussex, has been appointed a director as from November 1.

★ ★ ★

BUSINESS CHANGES

HEENAN AND FROUDE LTD., and the BRUSH GROUP, LTD., have sold the whole of the issued share capital of BRITISH OILFIELD EQUIPMENT CO. LTD., which was jointly owned by them, to CAMERON IRON WORKS, INC., Houston, Texas, U.S.A. British Oilfield Equipment will continue to operate under its present name and MR. EDWARD BENJAMIN will continue as managing director.

VARLEY PUMPS & ENGINEERING LTD., the English subsidiary company of FOOD MACHINERY and CHEMICAL CORPORATION of the U.S.A., have acquired the business of C. E. DOUGLAS & CO. LTD., 86 Strand, London, W.C.2. MR. T. A. S. JOHNSON, managing director of C. E. Douglas & Co., has been appointed a director of Varley Pumps. MR. J. H. BENTLEY, B.Sc. tech., A.M.I.Mech.E., chairman and managing director of Varley Pumps has been appointed chairman of C. E. Douglas & Co., and MR. W. DE BACK, a director of Varley Pumps has also been appointed to the board of C. E. Douglas & Co.

The directors of GEORGE ANGUS and CO. LTD., Angus House, 152-158 Westgate Road, Newcastle-upon-Tyne 1, have made an offer for the purchase of the whole of the preference and ordinary share capital in F. REDDAWAY & CO., LTD., subject to accountants' investigation, to acceptance being obtained from the holders of 90 per cent. of the issued ordinary and preference shares in F. REDDAWAY & CO., and the necessary consent on the part of the capital issues committee being obtained.

★ ★ ★

OBITUARY

We regret to record the deaths of:

LIEUT.-COLONEL PERCY JOHN COWAN, M.B.E., M.I.C.E., M.I.Mech.E., on November 15, who served on the editorial staff of ENGINEERING from 1906 and was Joint Editor from 1924 to 1938. Colonel Cowan had a strong aversion to obituary notices, which he expressed to us some time ago, and in accordance with his wishes we are not publishing the customary memoir.

MAJOR GEORGE HEDLEY, at Wonston, near Winchester, Hampshire, on November 4, at the age of 77. He began his steelworks career as an apprentice with Bolckow, Vaughan & Co. Ltd., Middlesbrough, and subsequently became managing director of the Linthorpe Dinsdale Iron Smelting Co. Ltd., Middlesbrough, and a director of the Bowesfield Steel Co. Ltd., Stockton. He was elected a member of the Iron and Steel Institute in 1900.

MR. JOHN WILLIAM SIMPSON MUSTART, M.B.E., at Tynemouth, Northumberland, on November 7, at the age of 77. He was formerly works manager, North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Mr. Mustart joined the firm as an apprentice engineer, and retired in 1943.

MR. ALBERT HARRY GINMAN, in Canada, on November 7, at the age of 79. A former President of the Canadian Marconi Co., he was born in Surrey, England, on December 14, 1874. Mr. Ginman joined the staff of Marconi's Wireless Telegraph Co. Ltd., in 1901 and worked with Marconi himself. He was transferred to the American Marconi Co. in 1902. In 1935, he became President of the Canadian Marconi Co., and general manager, in Canada, of Cable and Wireless Ltd. He relinquished his office of President of the Canadian Marconi Co. in January, 1951, but remained a member of the board.

SIR WALTER HARRY EVANS, Bt., at his home, the Mead House, Shipley, Wolverhampton, on November 7, in his 83rd year. Formerly a hydraulic engineer, he was for many years a director of Joseph Evans & Sons (Wolverhampton) Ltd., pumping machinery manufacturers, Wolverhampton, and was created a baronet in 1920 for services rendered to the Government during the war of 1914-18.

Contracts

RAILWAY-ELECTRIFICATION EQUIPMENT

A contract from British Railways for the supply and installation of overhead electrification equipment for an extension of the present Liverpool Street-Shenfield electric service as far as Chelmsford and Southend (Victoria), Essex, has been received by BRITISH INSULATED CALLENDER'S CONSTRUCTION CO. LTD. The extensions mean that a further 9¼ miles of route will be electrified between Shenfield and Chelmsford and a further 21¼ miles between Shenfield and Southend. The overhead equipment will be similar to that already installed. It will operate at 1,500 volts d.c., and on the main track, will utilise a compound catenary system consisting of hard-drawn copper strand as the main catenary, an auxiliary catenary supported by solid-copper dropper wires and a grooved cadmium-copper contact wire suspended from the auxiliary catenary by loop droppers. The three wires will be "jumpered" " together in every span and will provide a flexible system enabling trains to run at speeds of 70 m.p.h. It is hoped to complete the new electrification early in 1957.

Electric Motors and Alternators. As a result of relaxations in the control of exports to the Soviet Bloc, CROMPTON PARKINSON LTD., Crompton House, Aldwych, London, W.C.2, are now producing motors and alternators for Russia for the first time since the war. A substantial number of motors and alternators is involved; one order, just placed, is valued at £200,000. The motors are principally of 2-h.p. rating, suitable for machine-tool equipment, while the alternators are mainly of 512·5 kVA rating, designed for use in conjunction with Diesel power units. Most of the motors will be manufactured at the company's Guiseley Works, Yorkshire, and the alternators at the firm's Chelmsford Works, Essex.

Industrial Tractors. The Ministry of Supply have placed orders valued at £105,000 with DAVID BROWN TRACTORS (ENGINEERING) LTD., for industrial wheeled tractors. These machines will be used on United Kingdom civil airfields for general towing duties. The greater part of the tractors will be of the firm's new 30IDT type, which has a four-cylinder 34-b.h.p. Diesel engine, a new type single-stage turbo transmitter, and special wheel equipment. The gross weight is just over 3 tons and the standard equipment includes a six-position rear towing hitch and single front hitch. The remainder of the machines will be 30IC vehicles, fitted with heavy-duty towing winches. This model is driven by a four-cylinder 41-b.h.p. petrol engine with four-speed gearbox. The maximum road speed is 22 m.p.h.

Bulk-Grain Railway Vans. The British Transport Commission have placed a contract with the PRESSED STEEL CO., LTD., Cowley, Oxford, for 195 twenty-ton bulk-grain vans. The vans are to be constructed at the firm's Linwood Works, Paisley, Renfrewshire.

Water Turbines. The U.S. Army Corps of Engineers have announced that a contract for two 68,000 nominal h.p., 128·6 r.p.m., vertical-shaft single-runner Francis-type water turbines for the Table-Rock Dam power station has been placed with the ENGLISH ELECTRIC EXPORT AND TRADING CO. LTD. The turbines are to be suitable for operating at heads of from 134 to 228 ft., the nominal head being 190 ft. At 134 ft. head, the output of each turbine is 44,000 h.p., and at 228 ft., it is 83,200 h.p. Delivery will commence in August, 1956, and the equipment is due for completion by September, 1957. The turbines will be made at the English Electric Co.'s works in England.

Coke-Oven Plant. SIMON-CARVES LTD., Cheadle Heath, Stockport, have received from the Indian Iron and Steel Co. Ltd., through their consulting engineers, the INTERNATIONAL CONSTRUCTION CO., LTD., London, a contract for the building of two batteries, each of 78 coke ovens, with by-products plants and coal and coke-handling plants, at the Burnpur steelworks, in West Bengal. The total cost of the work will exceed £3 million. The new batteries will form an extension to an existing battery, completed by Simon-Carves Ltd. in 1950, and will add 3,500 tons of dry coal per day to the carbonising capacity at the Burnpur works. The total capacity of the Burnpur carbonising unit will be 6,300 tons a day. The whole of the designs and a portion of the equipment will be provided from Great Britain, but much of the brickwork and steelwork and many of the castings will be of Indian origin.

DESIGNING FOR THE EYE

Form and Utility in Engineering Products

In a world which depends so largely on the work of engineers, the designer has a great responsibility not only for the technical standard, but also for the appearance of his designs. This aspect of engineering was discussed in a public lecture entitled " Form in Engineering Design " delivered on November 2, at King's College, University of London, by Mr. J. Beresford Evans, a consulting designer.

An article was seen, Mr. Evans said, before it was understood; if this first impression proved pleasant a prospective user or buyer would feel more inclined to investigate the article further. Moreover, good design made a product easier to operate; a control panel which consisted of a haphazard collection of dials and wires, for instance, would prove very confusing to an aeroplane pilot and might hamper him seriously in an emergency. However, the broadest reason for encouraging good design was a social one: engineering forms dominated the street, the home and even the rural landscape.

Visual design presented a special problem to the engineer for, unlike architecture, engineering had no tradition of aesthetic enrichment; good appearance in engineering products arose from their character, and beauty could not be translated to them from other sources. Any attempt to conceal inherent features was unsatisfactory.

Fashion was a factor associated with the life of a product and could only be permitted in articles, such as motor cars, which were frequently replaced or exchanged. Motor cars also illustrated the tendency to borrow from other fields, for, although they were comparatively slow-moving objects, they had recently come to assume aerodynamic forms, which could not appreciably affect their performance. Fashion was in most cases a purely artificial trend and was often adopted merely to encourage an owner to discard his model of the previous year.

FUNCTION, UNITY AND ORDER

Function was the unifying factor of all products and unity was one of the principal conditions of good design. To achieve this the designer must endeavour to introduce order into the collection of separate members which comprised the whole. A machine tool which looked as if each new development had been added piecemeal without re-designing the original structure was cumbersome in appearance and consequently harder to handle. It was important that the product should be something recognisable, something that could be grasped by the mind as a single idea.

There were, Mr. Evans continued, certain guiding principles which might be adopted to direct, encourage and give confidence to the eye. The mind required a focus, a centre on which to settle and must not be left in doubt or unresolved. Pairs, for example, were confusing; if an article had two identical features, the eye hesitated between them, unable to come to rest on either. Moreover, it was often important to distinguish items which were similar in form but different in function, in order to assist the mind in making a decision.

The eye was easily guided; a circle, for instance, attracted the eye to its centre, a triangle had the reverse effect. The eye also liked to be certain; if a quadrilateral were not quite square but nearly so it created a sense of uneasiness. Any characteristic of an article should be used and not opposed, and detail in most cases should be given a more prominent finish than the surrounding bulk.

Directness and simplicity were very desirable qualities; a transparent insert giving an immediate reading of the liquid level in an oil stove, for example, was a much more satisfactory device than a float-operated dial gauge and was also less prone to damage. Aesthetics, in fact, often went hand in hand with efficiency.

Letters to the Editor

EASE OF READING PRINTED MATTER

SIR, May I comment—neither as an engineer nor as a printer, but only as a librarian—on the section of Mr. Westover's British Association paper on " Film-setting " (ENGINEERING, October 8, page 460), dealing with " justification." Mr. Westover gives the unfortunate impression that justification is merely " part of a printer's religion " and an unnecessary operation.

Modern justification—as distinct from the reasons why early printers used it—is required by the far smaller type sizes and often larger pages now used. Early printers soon produced types as small as the most delicate MS. writing, but such small types were usually employed in small formats. Folio volumes were printed in large type; ENGINEERING, for instance, would have been printed in what is now headline-size type. Modern folios and other large pages are now printed in type close to the sizes used in small books. Large volumes are no longer used as pulpit or reading-desk matter, or choir books to be used at group range, and large type is unnecessary. Paper can be saved, and bulk of book.

It was then discovered that to follow a line of small type, or writing, across a wide page is difficult for the reader. Smaller type must be set in narrow columns, because of the mechanics of the reader's eye. For ease of reading, each line must end in white space at the same place so that eye motion is uniform and automatic. Also, white space within the line—or characters and words within the line—must be distributed at least uniformly within the line, and within a narrow range when compared with other lines of the matter: witness ENGINEERING's change to wider white column breaks and a new type face at the beginning of the year. It is not as easy to read typewriting. Longer writing line, less blackness, requires larger type size. Typewriting reproduced photographically, down to the same size as a sample of printer's type, compares badly in legibility. Books reproduced from typewriting—even with the added legibility of electric typewriters—compare unfavourably with letterpress, and justification is at least one reason for this.

The necessity of lock-up remains with the printer, who could add spaces at the end of the line. Certain effects can be produced in this way, but the very slowness of reading which it forced is one reason why this unjustified material has greater impact on the reader. So the film-setting process retains " justification "—not as part of the printer's religion, but as an aid to the reader. Proposals have been made that type be " set square " :

SO THAT OF TYPE AS A UNIT
A BLOCK IS READ AT A TIME

What would this produce in legibility? I do not know for sure, but it would certainly produce untold problems for the letterpress printer, let alone for the filmsetter. Let Mr. Westover be satisfied that justification is a difficult process, but necessary to the transmission of information smoothly and rapidly.

Yours sincerely,
D. A. REDMOND,
Librarian.

Nova Scotia Technical College,
Box 1000, Halifax,
Canada.
October 28, 1954.

★ ★ ★

In a leading article in our issue of October 8, on "Nuclear Power and Coal," we stated that the Pimlico district-heating scheme was reported to save 330,000 tons of coal a year. This figure was quoted from the address to which we referred. The Westminster City Council have now pointed out that the consulting engineers' estimate of the saving was 11,000 tons per annum. Mr. Clift, the author of the address, considers that 3,300 tons would have been a reasonable estimate.

BOOK REVIEWS

Coal. Its Formation and Composition. By WILFRID FRANCIS. *Edward Arnold (Publishers), Limited*, 41 *Maddox-street, London, W.*1. (84*s.*)

All users of coal, domestic or industrial, know that it is a very variable article. The usual broad classification into the three main groups, lignite, bituminous coal and anthracite, gives but a rough indication of the nature of any particular sample. By far the greater part of the coals found in Great Britain fall within the bituminous class and the range covered by that term is indicated by the fact that a general division into steam coal, coke and furnace coal, gas coal, and household coal has been adopted. The hard steam coals are anthracitic in character and merge into the third main group. The grading at the other end of the scale is less gradual, although the black lignites found in Pakistan may fairly be described as semi-bituminous coals. Still earlier in the series, peat, which represents the first stage in the transformation of the plant tissues into coal, merges into the less mature lignites which do not greatly differ in composition from some peats.

The change which takes place in the ascending series from wood to the purest anthracite may be roughly indicated by the carbon content. Wood, the primary material from which coal is formed, contains about 50 per cent. of carbon by weight; peat contains some 57 per cent.; lignite, 65 per cent.; medium-rank bituminous coal, 88 per cent.; and high-grade anthracite some 97 per cent. The change is accompanied by a decrease in the hydrogen content from about 6 per cent. at the top of the scale to 0·6 per cent. at the anthracite end; the figures for oxygen are from about 43 per cent. to 1·8 per cent. Wood, in this generalised statement, covers a wide range of vegetable matter and the characteristic features of various coals may be determined by the nature of the plants from which they were formed. During the long period over which the coal measures were formed, there was a progressive development of plant life from primitive forms to flowering plants approximating to those of to-day. A long chapter in this major work deals in detail with the structure of the coal-forming plants and points out that the geological history of any coal deposit will tend to determine its nature equally with the type of plant tissue from which it was formed.

In this country, interest in the complicated range of materials covered by the word "coal" is naturally concentrated mainly on the bituminous range, apart from the high-grade anthracites of South Wales. Peat is of importance in Ireland, where it is estimated to cover one-seventh of the total area, and there are lignite deposits at Bovey Tracey in Devonshire, but it is with bituminous coals that the majority of users are concerned. Chief interest is, of course, in the heating power; some are particularly concerned with coking properties and others with adventitious inorganic constituents. Of these, sulphur has attracted the most public attention in view of its contribution to atmospheric pollution. Sulphur is a constituent of some plant proteins and may be introduced during coal formation by infiltration from sulphate-bearing rocks. Coal may, however, contain many other constituents such as fluorine, phosphorus, boron, germanium and vanadium. Fluorine, like sulphur, has in some cases contributed to undesirable atmospheric pollution.

This authoritative book is concerned, as its title indicates, with the formation and composition of coals, not with their practical utilisation. None the less, it is of immediate and direct interest to fuel users. The early chapters, which describe in detail the structure of coal-forming plants and chemical and physical changes which take place in the formation of peat from vegetable matter, and lignites from peat, contain the fundamental information leading up to the consideration of the composition and properties of coals. Fuel technologists, one of whose duties may be said to be the study of the better utilisation of coals, will approach their many problems the more effectively the better they are acquainted with the history of the processes by which coals increase in rank as they depart further from the original plant debris from which they were formed.

The earliest method of classifying coals was based on the assessment of the carbon, hydrogen and oxygen contents. This relatively elementary procedure has been replaced by others based on ultimate analysis. This matter is dealt with in great detail and is followed by a chapter on the composition of mature coals. In this, some of the problems of practice are approached in the account of coal assay by destructive distillation. It is suggested that the Gray-King and Fisher assays are best used at relatively low temperature. They give, however, valuable information in carbonisation processes and also on the use of coal as fuel. The B.M.A.G.A. assay devised by the U.S. Bureau of Mines and the American Gas Association gives additional information on tar and gas yields. It is stated that hydrogenation, of great practical value in producing oils from coal, has not been helpful in elucidating problems of coal structure. This voluminous work is not confined to the coals of Great Britain; its field is the world. With its many illustrations, diagrams and tables, and its detail treatment of every aspect of its subject, it is a major contribution to scientific literature.

* * *

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Mobile Generating Sets. ENGLISH ELECTRIC CO., LTD., Foregate-street, Stafford. Illustrated descriptions of Diesel-engine-driven package sets, road trailer sets and rail vehicle sets with outputs from 172 to 1,240 kW. Full technical details, ratings, dimensions and outputs. Intended for use where a temporary power supply is required for short periods, as on civil engineering projects and mine and oil exploitations.

Crawler Tractor Equipment. JOHN FOWLER AND CO. (LEEDS), LTD., Hunslet, Leeds 10. Type-A cable control unit and Bray hydraulic angledozer. Both for use with Fowler Challenger-1 Diesel crawler tractor. Two leaflets giving detailed specifications.

Magnetic Separators. GASTON E. MARBAIX LTD., Devonshire House, Vicarage-crescent, London, S.W.11. Automatic magnetic coolant separator. Self-contained Mechanically operated units for capacities from 8 to 80 gallons per minute. Illustrated pamphlets giving full details.

Streetlighting. BRITISH THOMSON-HOUSTON CO. LTD., Rugby. "Mazda" lamps and streetlighting equipment. Illustrated booklet reviewing current practices in streetlighting: lantern design and location; economies, recommendations, specifications and codes of practice; calculations.

Miniature Recorder. EVERSHED & VIGNOLES, LTD., Acton-lane Works, London, W.4. Miniature recorder for voltage, current or temperature. Fixed or portable models. As used in process controllers. (See ENGINEERING, vol. 177, page 535, 1954.) Leaflet No. 282 gives details.

Radio and Television Components. THE PLESSEY CO., LTD., Ilford, Essex. Components for radio and television circuits including coils, transformers, capacitors, potentiometers and speakers. Booklet giving full technical details, performance curves and frame circuits.

Navigation Plotting. MARCONI INTERNATIONAL MARINE COMMUNICATION CO., LTD., Chelmsford. "Locatorgraph" plotting system for ships, used in connection with radar. Illustrated booklet explains alternative methods and gives examples.

Fluorescent Lighting. THORN ELECTRICAL INDUSTRIES, LTD., 105-109 Judd-street, London, W.C.1. "Atlas" fluorescent lighting equipment. Technical handbook gives principles, circuits and range of fittings available.

Electronic Recorder. CAMBRIDGE INSTRUMENT CO., LTD., 13 Grosvenor-place, London, S.W.1. Sensitive electronic recorder primarily for small d.c. potentials. Up to 6 circuits can be used. Leaflet No. 321 gives full particulars.

Steam-raising Plant. BABCOCK & WILCOX, LTD., Babcock House, Farringdon-street, London, E.C.4. Development of boilers and furnaces with examples of present-day plant. Illustrated brochure No. 1535/1; also available in Spanish and Portuguese.

Remote Control by Imposed Ripple. AUTOMATIC TELEPHONE & ELECTRIC CO., LTD., Strowger House, Arundel-street, London, W.C.2. Non-technical description of Rythmatic ripple control system, particularly for street lighting. Illustrated brochure.

Traffic signals. AUTOMATIC TELEPHONE & ELECTRIC CO., LTD., Strowger House, Arundel-street, London, W.C.2. Vehicle-actuated traffic lights. Description and discussions of types available. Illustrated booklet.

Switches and Indicator Lamps. ARCOLECTRIC (SWITCHES), LTD., Central-avenue, West Molesey, Surrey. Miniature and standard lighting switches; mains and low-voltage indicating lamps and holders. Illustrated catalogue No. 128.

Diesel-electric Shunting Locomotive. ENGLISH ELECTRIC CO., LTD., Queen's House, Kingsway, London, W.C.2. 400-h.p. Diesel-electric shunting locomotive. Brochure TD/102A gives performance and particulars.

Cast Iron Resistance Grids. JOHN HARPER & CO., LTD., Willenhall, Staffordshire. Technical data of grids with resistances between 0·4 and 0·013 ohms, of which 50 standard patterns are made.

Heating Vibrator Screens. MODERN TRANSFORMER CO., LTD., Moxley-road, Bilston, Staffordshire. Electric heating units for vibrator screens to prevent blinding. Leaflet gives some particulars.

Heavy Alloy. GENERAL ELECTRIC CO., LTD., Magnet House, Kingsway, London, W.C.2. Development, uses and properties of the G.E.C. heavy alloy, particularly for aircraft. Illustrated booklet.

Lifting and Moving Tackle. FELLOWS BROTHERS, LTD., Cradley Heath, South Staffordshire. Crabs, blocks, cranes, hoists and jacks. Illustrated catalogue, edition 54.

Private Telephones. COMMUNICATION SYSTEMS, LTD., Strowger House, Arundel-street, London, W.C.2. Particulars and possibilities of 25-line automatic telephone exchange. Illustrated booklet.

Alloys and Electric Cables. TELEGRAPH CONSTRUCTION & MAINTENANCE CO., LTD., Greenwich, London, S.E.10. "Telecon" products including cables, alloys and plastics. Illustrated leaflet.

Cable Cleat. EVERSHED & VIGNOLES, LTD. Acton-lane Works, London, W.4. Moulded cable cleat with spring clips. Illustrated leaflet No. 055.

Flameproof Lighting Fittings. E. N. MACKLEY & CO., Hawks-road, Gateshead 8. Flameproof lighting fitting and junction box. Illustrated leaflet M.15.

* * *

BOOKS RECEIVED

Some of the books noticed in the Books Received column are selected for extended review in later issues of ENGINEERING.

Water Conditioning for Industry. By SHEPPARD T. POWELL. *McGraw-Hill Book Company, Incorporated*, 330 *West* 42*nd-street, New York* 36, *N.Y., U.S.A.* (9 dols.); and *McGraw-Hill Publishing Company, Limited*, 95 *Farringdon-street, London, E.C.*4. (64*s.*)

Specific methods of water conditioning are described in detail, with information on design features, control required for effective performance, and installation and operating costs. Problems of corrosion control, embrittlement of boiler steel, and steam quality are dealt with, and the treatment of water for high-pressure boilers is emphasised. A review of the latest types of evaporation and de-aeration equipment, treatment of water in recirculating systems, silica removal, and "acidising" of equipment to remove deposits, is also included.

Dust is Dangerous. By C. N. DAVIES. *Faber and Faber, Limited*, 24 *Russell-square, London, W.C.*1. (21*s.*)

The understanding of the dangers of dust, the assessment of dust concentrations and the measures adopted to eliminate dust hazards, are described in this book, which is fully illustrated. It will be of interest to those concerned with occupational hygiene in a wide variety of industries.

Active Networks. By VINCENT C. RIDEOUT. *Constable and Company, Limited*, 10-12 *Orange-street, London, W.C.*2. (42*s.*)

This book is intended primarily for those who have studied the physics of vacuum tubes and related devices as well as the fundamentals of the theory of passive linear networks. Vacuum tube networks capable of amplification have been covered, the emphasis being on vacuum tube circuits as applied to

communication and control engineering. The transistor is also dealt with in considerable detail, and sections have been included on thyratrons, magnetic amplifiers, and the position-controlled servo-mechanism.

"Cassel" Manual of Heat-Treatment and Case-hardening. Sixth edition. *Imperial Chemical Industries, Limited, Sales Office, Gloucester House, 149 Park-lane, London, W.1.* (15*s.*)

This manual is intended primarily to provide particulars of I.C.I. molten salt baths and processes for the heat-treatment of ferrous metals, but an elementary introduction to the metallurgical factors involved in processing the steels mentioned has also been included. The object has been to cater for those who have little metallurgical knowledge, particularly the many engineering works without trained metallurgical staff.

Analog Methods in Computation and Simulation. By WALTER W. SOROKA. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (7·50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (53*s.* 6*d.*)

This book describes mechanical, electro-mechanical, electrical and electronic analogue components for performing basic mathematical operations, and shows how such components may be combined into mathematical machines for solving sets of simultaneous linear algebraic equations, polynomial equations, and differential equations of all kinds. The last three chapters show how dynamical analogies, finite difference networks, membrane analogies, and conducting sheets of uniform and variable thickness may be applied to the simulation of various physical systems, and to the solution of differential equations.

SIR GEORGE CAYLEY

EARLY FLYING EXPERIMENTS

Sir George Cayley, 1773-1857, is to-day generally associated with the science of aeronautics, and in his lifetime was designated "the father of aerial navigation" by W. S. Henson. In the first Cayley Memorial Lecture, entitled "Sir George Cayley, Bart., The Father of British Aeronautics," given before the Royal Aeronautical Society in Brough on Thursday, November 4, the lecturer, Captain J. Laurence Pritchard, C.B.E., Hon. F.R.Ae.S., reminded his audience that Cayley's scientific interests and achievements in fact ranged over a much wider field.

Sir George Cayley, Captain Pritchard said, played a large part in fostering the founding of the British Association, and he initiated the idea of the Polytechnic Institution which was set up in Regent-street in 1839, for research and teaching in engineering and science.

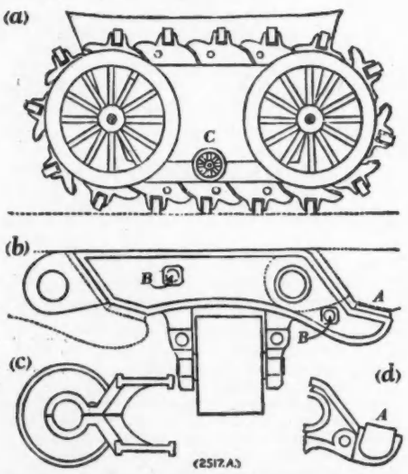


Fig. 1 Cayley's "Universal Railway" (Patent No. 5260, 1825)—the forerunner of the crawler tractor.

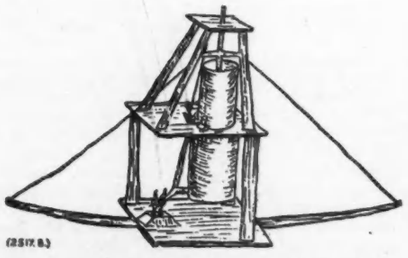


Fig. 2 An experimental gunpowder explosion engine; the piston was returned by a bow or spring.

For over 30 years Cayley was the chairman of the body responsible, under the Muston Drainage Act, for the effective drainage of large areas in Yorkshire, and in 1856, at the time of the great floods in France, he published in the *Mechanics' Magazine* a guide to methods of flood control.

Cayley invented the caterpillar tractor. In the *Mechanics' Magazine* for January, 1826, appeared the astonishing drawing shown in Fig. 1. "This invention, which may be called the universal railway, is for the purpose of forming locomotive vehicles by which the impediments and resistances of every sort of road, land, morass or water will be obviated or overcome," wrote Cayley.

In Cayley's gunpowder engine (Fig. 2), a piston was driven upwards by the force of the explosion of a given amount of powder and brought back after the explosion by a bow or spring. He abandoned it in favour of the hot air expansion engine, with which he experimented for the next 40 years. Discussing it, he said "a much cheaper engine of this sort might be produced by a gas-tight apparatus and by firing the inflammable air generated with a due proportion of common air under a piston." He suggested oil of tar for the explosive fuel.

In the field of railways, he suggested that compressed air buffers should be used in addition to spring buffers, and that the compression of the buffers could be used to apply the brakes automatically. He schemed out in detail an automatic block system of control, making allowance for the expansion and contraction of a mile length of controlling wires so that the wire would always be at the same tension. He suggested that there should be automatic signals in the driver's cab indicating how the points were set.

Among his other interests were optics, a self-righting lifeboat, the absolute temperature zero, the permanent defence of the country against attack from the Continent, architecture, the acoustics of buildings, and the study of natural flight.

In aeronautics, Sir George Cayley was the first to clarify the confusion of ideas about mechanical flight, and to lay down the principles of heavier-than-air flight; to carry out experiments in aerodynamic research, for flying purposes, on the pressure on surfaces at various angles of incidence, and to use models for flying research (his whirling-arm apparatus is shown in Fig. 3); to draw attention to the importance of streamlining and to outline the body of least resistance; to show and discuss the movement of the centre of pressure of a surface in an air stream, to discuss the problem of stability of an aeroplane, and to indicate methods to obtain stability; to draw attention to the effects of the dihedral angle for wings, and of a movable tail plane and rudder; to draw attention to the great importance of weight control, and of the power/weight ratio, and of finding a light prime mover; to design a light aeroplane wheel; to build a man-carrying glider; to point out that curved surfaces had a better lift than plane surfaces, and that there existed a region of "vacuity" on the top surface; to suggest water recovery for airships; to suggest the "internal explosion" (i.e., combustion) engine for aircraft; to suggest jet reaction for propelling and steering air vessels; to suggest the convertiplane, i.e., the combination of the fixed wing surface and vertical lift surfaces.

In Fig. 4 is shown Cayley's proposal which contained all the performance ideas for the convertiplane—the revolving blades AA and BB for take-off, and the airscrews GG for horizontal flight, AA and BB then becoming fixed surfaces. The circular planes were contra-rotating to eliminate torque, and the machine had a movable horizontal tail and rudder. This was Cayley's machine capable of "landing at any place capable of receiving it, and of ascending from that point and "capable of remaining stationary, or nearly so, in the air."

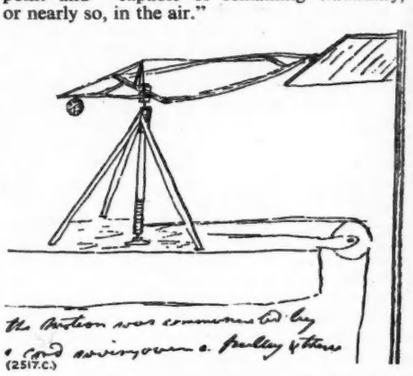


Fig. 3 Cayley's whirling arm apparatus for early experiments in flying.

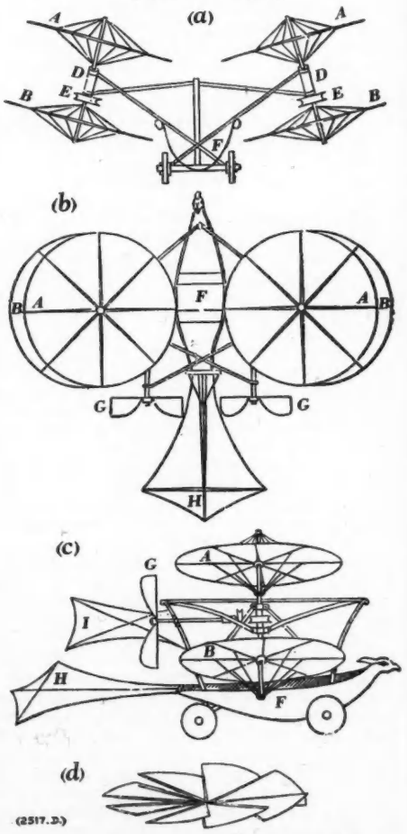


Fig. 4 Cayley's Aerial Carriage, embodying the idea of the "convertiplane."

The Institution of Naval Architects Autumn Meeting (concluded from page 624)

THE SIDE LAUNCHING OF SHIPS

MODEL AND FULL-SCALE EXPERIMENTS

The concluding paper read at Torquay during the Autumn Meeting of the Institution of Naval Architects was presented on the morning of Friday, September 24, by Mr. D. J. Doust, B.Sc., with Mr. R. B. Shepheard, C.B.E., B.Sc., Chairman of the Council, presiding. It discussed "Side Launching of Ships, with Special Reference to Trawlers," and was followed by films demonstrating the side launching of model hulls in one of the tanks at the National Physical Laboratory, and full-scale side launches of trawlers.

ROLL EFFECTS

The work described was carried out at the instigation of Messrs. Cook, Welton and Gemmell, Limited, Beverley, Yorkshire, in whose shipyard side-launching is normally employed. Full-scale results obtained in that yard were compared with those derived from a series of model experiments conducted by the Ship Division of the National Physical Laboratory. A representative trawler was selected as the basic form for the investigation. The process of side-launching was considered in three separate stages, namely, from the initial position at rest at the top of the ways, down to the quay edge; from the time that the centre-line of the vessel passed the way ends, up to the instant of impact of the hull on the water surface; and from the point of impact to the final position of rest. The metacentric height largely governed the maximum angle of roll assumed after the impact, which occurred when the vessel was partly immersed but was still moving vertically downward. The magnitude of the angle was affected also by the depth of water into which the vessel was launched. The maximum return angle of roll, towards the quay edge, was perhaps a more dangerous factor; it depended to a marked extent on the metacentric height and the velocity at the way ends. If the static drop was excessive, the return roll could be sufficient to cause the vessel to strike the quay edge. In the model experiments, the bed and banks of the River Hull in the vicinity of the shipyard were reproduced to a scale of 1 : 12. A series of brass rollers took the place of the standing ways. The velocity of the model was recorded electrically, and the angular motion by triple gyroscopes, fitted in the model as part of the ballast; they were sensitive to the angular motion of the model in three mutually perpendicular planes and supplied an out-of-balance current proportional to the yaw, pitch and roll throughout the entire motion. The clearance of the bottom of the keel at the after perpendicular was observed photographically. In the case of the full-sized ship, the velocity down the ways was recorded by a high-speed cine-camera, fitted with a tuning-fork device which made an impression on the film at millisecond intervals. Analysis of the film enabled the distance-time curve to be deduced, and from that curve the velocity and acceleration curves were obtained graphically. The triple gyroscopic recorder was also mounted on board the vessel before the launch. Inclining experiments, conducted after the launch, enabled the metacentric height in the "as launched" condition to be determined.

DISCUSSION

The discussion was opened by Mr. A. Hiley, who considered the paper to be one of extreme value, particularly in connection with the calculated and observed behaviour of actual ships and the corresponding investigations on models, using delicate apparatus for the measurement of velocities, angles of heel, the effect of the radius of gyration, and moments of inertia. The work might be extended to see the effects of water on the way ends. The paper was almost to be regarded as supplementary to the very able and informative treatment of the side-launching problem on the Great Lakes by Mr. James Fahey, published in 1942; he also connected the results thoroughly as between model and ship, and dealt with the launching of submarines and also of very long ships of restricted width. Velocity was a very important factor, and in the paper the velocities were shown on an abscissa of metacentric height. Perhaps a little more information might be given regarding the effect of producing curves which, on a base of travel beyond the way end, would represent the angle of heel and trajectory of the ship as she continued and fell over the ways. He thought, however, that the base taken was in agreement with Fahey's treatment of the subject. Some assistance might be given, where a vessel had to be launched in a restricted width of water, by arranging the declivity so that there would be an increasing decline as the vessel reached the way end. He also suggested that it might be better to have the water level higher at the end of the ways.

LAUNCHING CONTROL BRAKE

The 1,000-tons deadweight barges of the first World War had the same length as the trawler mentioned in the paper (180 ft.) and the other dimensions were the same, but they had twice the displacement at launching, i.e., more than 800 tons. To avoid damaging the bottoms of those ships as they passed over the way ends, it was necessary to have a considerable amount of water on the way ends, at least 1 ft. In arranging for the launching, he had to deal with a velocity over the way ends of 16 ft. per second, compared with the average of 10 ft. per second mentioned in the paper. The vessels came to rest with an angle of heel not exceeding 15 deg, which was moderate. In a test it was necessary to push the vessel forward so that she did not hesitate on the ways, and she went over with a marked increase of velocity. That was done by applying pressure behind compressible pads of soft wood. Mr. Hiley then produced a model of a brake which, he claimed, would control a ship when side-launched. It consisted of a hawser passing through a brake drum. The hawser could be connected with the upper part of the ship, and, at a given stage in the launching, brought into action; it could be allowed to pull through against a given resistance, which could be kept to a moderate and well-regulated value. That would prevent the imposition of unwanted stresses, and the vessel could be brought to rest at a short distance from the way end. He suggested that it could be applied with advantage in restricted waters, whether the launching was end on or otherwise, as it would give full control of even a long ship, in a river like the Tyne, where it might be necessary to stop a ship in 100 ft. after leaving the launchways.

Mr. C. W. R. King, referring to the comparison of ship results with model predictions in the paper, observed that, with trawlers Nos. 4 and 6, the equivalent G.M. was very high as compared with the basic trawler No. 1, and yet there was a great variation in the maximum outward angles of roll, 28·0 deg. and 32·25 deg. respectively, whereas the maximum return angles of roll did not show such a great variation. In view of the slightly increased velocity and the much higher equivalent G.M., could the author explain why those differences existed, compared with trawler No. 1? He noted that there was a difference in static drop between trawlers Nos. 4 and 6 (3 ft. 7 in. and 4 ft. 3½ in., respectively). Would that mean that the difference in static drop would have a greater effect on the angles than the G.M. of the ships, particularly as trawler No. 6 had such a high equivalent G.M.? Would it be a fact, apart from any braking apparatus or anything to check the angle, that a high G.M. of the vessel when leaving the ways and entering the water (before it was fully water-borne) had no effect at all, or very little? It appeared to him that the static drop was much more important than the G.M. Would an increase in the declivity of the slip, without actually lowering the slip at the water end, be effective in virtually reducing the static drop and therefore bringing the outward angle much lower in the other case?

RIVER LAUNCHING

Mr. Ambrose Hunter, managing director of Messrs. Cook, Welton and Gemmell, Ltd., in a letter which was read by the Secretary of the Institution, expressed the thanks of the company for the very useful practical research undertaken at the company's request by the National Physical Laboratory. The letter continued:—"Cook, Welton and Gemmell have successfully launched sideways for upwards of 50 years. With increase in dimensions, change in form and the limitations of the River Hull, it was felt that the mechanics of sideways launching should be studied. The results of the research undertaken by the National Physical Laboratory do enable successful sideways launching to be arranged for all conditions of constructional progress, weather conditions and level of tide. Records continue to be taken of sideways launching at the Beverley shipyard with a view to the information obtained being correlated with further model research by the National Physical Laboratory on other types of ships. By this means it is hoped to establish clearly the upper practical limit of production from the Beverley shipyard."

Mr. Colin Bartlett, O.B.E., said that the author had rightly stressed the danger point; what was more important to the shipowner was the limit-of-safety point.

Captain Harold E. Saunders, U.S.N. (ret.), in a communication read by the secretary, wrote that, for side launches it was most illuminating to have a step-by-step picture of what happened in a transverse plane, beginning at the instant the centre of gravity passed the way ends. What he had in mind was a diagram drawn to a large scale, showing the actual position of the ship section at equi-distant time intervals Δt. Such a diagram would indicate not only the minimum bed clearance under the low bilge (and bilge keel) at the first roll outward, but the amount by which the trailing bilge (or bilge keel) cleared the way ends when the ship rolled back towards the slip. It would also show the obliquity of water impact under the hull for the side launch of a vessel with a large rise of floor.

AUTHOR'S REPLY

Mr. Doust, replying to the discussion, admitted that the possible extension of the length of side-launched vessels needed further investigation. Mr. Hiley's use of a compressed block to give a high starting velocity in launching, applying the principle of residual strain energy, was most interesting, and should be followed up by those in the industry. Similarly, the use of the cable passing through the brake drum, giving very accurate control of the motion and absorbing the energy which had to be dissipated, would have an application not only to side launching; he was sure those concerned with end-on launching also would be interested. The use of drags to arrest motion not only tore up the ground, but might be a source of considerable danger to personnel; there were cases on record where they had resulted in serious injury. Mr. King had raised a very interesting point. The vertical height of the centre gravity had two effects on the subsequent motion. Gravity affected the motion at the way end. Obviously, a higher centre of gravity would give a higher moment at any instant, and generally the rotation would be increased; but an additional effect was a dynamic one, that when the vessel was in the water there was also a higher centre of gravity for a constant height of metacentre. That involved a reduced metacentric height, and there was a further loss of velocity. In correspondence, he would quote figures which bore out that point.

STRESSES IN SHORT BEAMS

2—THEORETICAL ANALYSIS AND CONCLUSIONS

*By J. S. Caswell**

Concluded from page 628

In Part 1 of this article, on page 625 of last week's issue, a description was given of the experimental investigation of the stresses generated in beams having a low span-depth ratio. In that article repeated reference was made to the Stokes-Wilson theory of stress distribution in such beams. Part 2, herewith, is a brief discussion of that theory and indicates the derivation of the expressions that were used in Part 1 to analyse the experimental results.

Stresses Produced by Point Loads.—The stresses produced by a concentrated point load applied to the surface of an elastic body can be determined by using the three-dimensional solution of Boussinesq.† In this way Flamant‡ found that, for the element shown in Fig. 9, herewith,

$$\text{the radial stress, } \sigma_r = -\frac{2P_1\cos\theta}{\pi r}, \quad . \quad . \quad . \quad (1)$$

$$\text{the tangential stress, } \sigma_\theta = 0,$$

$$\text{and the shear stress, } \tau_{r\theta} = 0.$$

It may be proved that these are correct solutions by verifying that the stress function

$$\phi = -\frac{P_1 r\theta\sin\theta}{\pi}, \quad . \quad . \quad (2)$$

satisfies the stress equations and also the compatibility equation.

Longitudinal and Transverse Stresses.—For the element "*a*" in Fig. 10 (*a*), the opposing stresses may be replaced by the stress system shown in Fig. 10 (*d*). Assuming unit thickness and $b\,c = 1$, then, from Fig. 10 (*b*), $d\,e = \cos\theta$. Then, from Fig. 10 (*c*) and (*d*),

$$\sigma_x' = \sigma_r\cos^2\theta.$$

Similarly,

$$\sigma_y' = \sigma_r\sin^2\theta,$$

$$\text{and } \tau_{xy}' = \sigma_r\sin\theta\cos\theta.$$

If x and y are the co-ordinates of the element a,

$$\cos\theta = \frac{x}{r}, \ \sin\theta = \frac{y}{r} \text{ and } r = (x^2+y^2)^{\frac{1}{2}}.$$

Then using the value of $\sigma_r = -\dfrac{2P_1\cos\theta}{\pi r}$

$$\sigma_x' = -\frac{2P_1x^3}{\pi(x^2+y^2)^2}. \quad . \quad (3)$$

$$\sigma_y' = -\frac{2P_1xy^2}{\pi(x^2+y^2)^2}. \quad . \quad (4)$$

$$\tau_{xy}' = -\frac{2P_1x^2y}{\pi(x^2+y^2)^2}, \quad . \quad . \quad (5)$$

where P_1 is the load on unit width.

For a width t and load P, the load on unit width is $P_1 = \dfrac{P}{t}$ lb., and when $\theta = 0$ (i.e., $y = 0$), the radial stress at a distance r below the point of loading becomes

$$\sigma'_{r(\theta=0)} = -\frac{2P}{\pi x t}. \quad . \quad . \quad (6)$$

For a supported block of finite form, Wilson§ showed that σ_r was not exactly proportional to $\dfrac{1}{x}$, but was proportional to $\dfrac{1}{(x+e)}$, where e is a small constant correction.

Application to a Centrally Loaded Beam.—For the finite form comprising a beam supported and loaded as shown in Fig. 11, the radial stress σ_r at B must be zero when $x = 2c$. This requirement led Stokes* to assume that the radial stress σ'_r is diminished by a stress, of an opposite kind and which is proportional to the distance below the upper edge, such that

$$\sigma_{r(\theta=0)} = -\frac{2P}{\pi x t} + \mathrm{K}x.$$

Then for $x = 2c$,

$$\sigma_{r(\theta=0)} = -\frac{2P}{\pi(2c)t} + \mathrm{K}(2c) = 0.$$

Therefore,

$$\mathrm{K} = \frac{P}{2\pi c^2 t}.$$

Then for the mid-section of the beam, the radial stress or transverse stress is assumed to correspond to the value calculated from the expression,

$$\sigma_{r(\theta=0)} = \sigma_x = \frac{2P}{\pi t}\left(\frac{x}{4c^2} - \frac{1}{x}\right). \quad . \quad (7)$$

Stokes also pointed out that the load P produces longitudinal stresses at all points of the section AB (Fig. 11) and that they vary according to a linear law. An examination of the force system near the point of load contact, as shown in Fig. 12, opposite, shows how these additional longitudinal stresses are produced. Resolving the forces over one half of the arc of radius r, as in Fig. 12.

$$\mathrm{F} = \int_0^{\frac{\pi}{2}} \sigma_r\sin\theta\, t\, r\, d\theta,$$

where

$$\sigma_r = -\frac{2P\cos\theta}{\pi t r}.$$

On substituting for σ_r and integrating, the resultant force is given by

$$\mathrm{F} = \frac{P}{\pi}. \quad . \quad . \quad . \quad . \quad (8)$$

The force system may then be approximately represented as shown in Fig. 13, and the bending moment at the mid-section, AB, is given by

$$\mathrm{M} = \frac{P}{2}l - \mathrm{F}c = \frac{Pl}{2} - \frac{Pc}{\pi},$$

and the corresponding longitudinal stress at B is

$$\sigma'_{y(x=2c)} = \sigma'_t = \frac{Mc}{I} = \frac{Mc\,12}{t(2c)^3} = \frac{3P}{2c^2t}\left(\frac{l}{2} - \frac{c}{\pi}\right).$$

The stress at a point N, Fig. 14, distant x below the upper edge, is given by

$$\frac{\sigma'_y}{\sigma'_t} = \frac{x-c}{c}.$$

Hence,

$$\sigma'_y = \frac{3P}{2c^3t}\left(\frac{l}{2} - \frac{c}{\pi}\right)(x-c). \quad . \quad (9)$$

In addition to this stress, there is also a stress of uniform value, σ_{yu}, which is superimposed on the stresses due to bending. This stress is given by

$$\sigma_{yu} = \frac{F}{2ct} = \frac{P}{2\pi ct}. \quad . \quad (10)$$

Resultant Longitudinal and Transverse Stresses.—The final form of the Stokes-Wilson equation for the longitudinal stresses is

$$\sigma_y = \sigma_y' + \sigma_{yu}$$

or

$$\sigma_y = \frac{3P}{2c^3t}\left(\frac{l}{2} - \frac{c}{\pi}\right)\left(x-c\right) + \frac{P}{2\pi ct}, \quad (11)$$

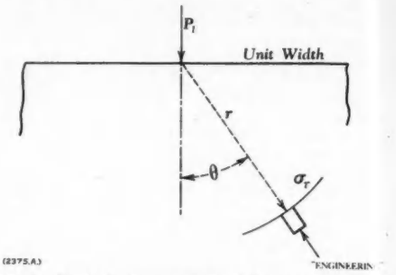


Fig. 9 Radial stress produced by an edge load.

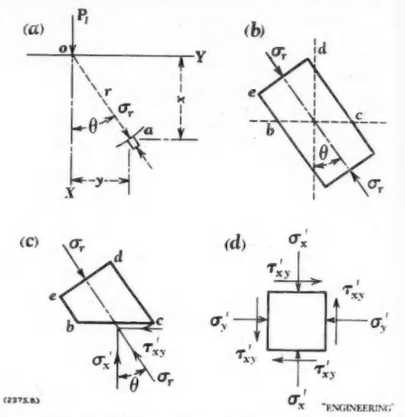


Fig. 10 Equivalent stress systems produced by an edge load.

and, as found earlier, the transverse stress along the mid-section is given by equation (7).

STRESS-EQUATION CHARACTERISTICS

The characteristics of these equations are considered below, for (*a*) the longitudinal stress, (*b*) the transverse stress and (*c*) the maximum shear stress.

The Longitudinal Stress Equation.—The value of x for constant stress σ_y'' can be determined as follow: using the parametric values, P_2, l_2 and P_3, l_3, and writing $x = x''$, then with σ_y'' constant,

$$\sigma_y'' = \frac{3P_2}{2tc^3}\left(\frac{l_2}{2} - \frac{c}{\pi}\right)(x''-c) + \frac{P_2}{2\pi ct}$$

$$= \frac{3}{2}\frac{P_3}{tc^3}\left(\frac{l_3}{2} - \frac{c}{\pi}\right)(x''-c) + \frac{P_3}{2\pi ct}.$$

Therefore,

$$x'' - c = \frac{2c^2(P_3 - P_2)}{3\pi(P_2l_2 - P_3l_3) + 6c(P_3 - P_2)}.$$

But $P_2l_2 = P_3l_3 = M$, therefore $x'' - c = \dfrac{c}{3}$

and since $c = \dfrac{D}{2}$,

$$x'' = \frac{2D}{3} \quad . \quad . \quad (12)$$

Therefore, at $\dfrac{2D}{3}$ below the upper edge, the longitudinal stress is the same for all span-depth ratios.

Also,

$$\frac{d\sigma_y}{dx} = \frac{3P}{2tc^3}\left(\frac{l}{2} - \frac{c}{\pi}\right), \quad . \quad (13)$$

which is constant for any given load P.

The particular value of x, x_0, equivalent to a zero value of σ_y, can be determined thus. By reference to Fig. 15 and equation (11),

$$\frac{3P}{2tc^3}\left(\frac{l}{2} - \frac{c}{\pi}\right)(x_0 - c) = -\frac{P}{2\pi ct}.$$

Hence,

$$x = x_0 = \frac{c(3\pi l - 8c)}{3(\pi l - 2c)}. \quad . \quad (14)$$

* Senior Lecturer, Mechanical Engineering, University College, Swansea.

† Boussinesq, *Comptes Rendus*, page 1510, vol. 114 (1892).

‡ Flamant, *Comptes Rendus*, page 1465, vol. 114 (1892).

§ Carus Wilson, "On the Influence of Surface Loading on the Flexure of Beams," *Phil. Mag.*, page 481, vol. 32 (1891).

* G. G. Stokes, *Mathematics and Physics Papers*, page 238, vol. 5.

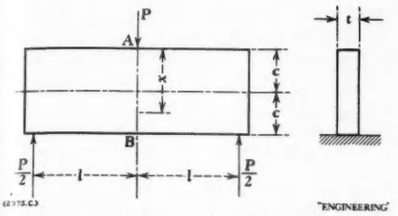


Fig. 11 Loading for the beams of series B.

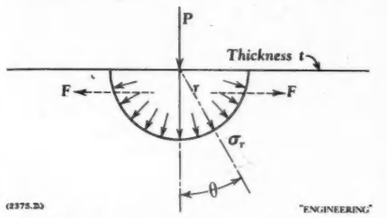


Fig. 12 Resultant horizontal components of the radial stresses.

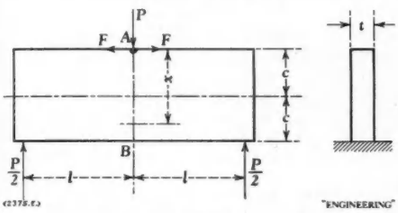


Fig. 13 Equivalent force system.

The values of the maximum longitudinal stresses, σ_t, σ_c, generated at the lower and upper edges of the beam can be determined as follow. Let σ_0 be the maximum fibre stress obtained by the simple theory, then, in triangles EBQ and HJQ in Fig. 15,

$$\frac{\frac{\sigma_0}{D}}{\frac{2}{2}} = \frac{\sigma_y''}{\frac{2D}{3} - \frac{D}{2}}.$$

Therefore,

$$\sigma_y'' = \frac{\sigma_0}{3}.$$

In triangles CBG and HJG,

$$\frac{\sigma_t}{D - x_0} = \frac{\sigma_y''}{\frac{2}{3}D - x_0} = \frac{\frac{\sigma_0}{3}}{\frac{2D}{3} - x_0}.$$

Substituting the value for x_0 obtained from equation (14) and cancelling,

$$\sigma_t = \left(1 - \frac{4c}{3\pi l}\right)\sigma_0, \quad . \quad (15)$$

and this is the longitudinal tensile stress at the lower edge of the beam.
Also, from triangles ECH and HFD,

$$\frac{\sigma_0 - \sigma_t}{\frac{D}{3}} = \frac{\sigma_0 - \sigma_c}{\frac{2D}{3}}.$$

Substitution for σ_t and D gives

$$\sigma_c = \left(1 - \frac{8c}{2\pi l}\right)\sigma_0, \quad . \quad (16)$$

which is the longitudinal compressive stress at the upper edge of the beam.

With progressive decrease in σ_c as the span-depth ratio decreases, equation (16) indicates that there is a certain span-depth ratio at which the longitudinal compressive stress at the upper edge will be zero:

$$\sigma_c = 0, \text{ when } 1 - \frac{8c}{3\pi l} = 0,$$

that is, for a given span-depth ratio,

$$\frac{S}{D} = \frac{l}{c} = \frac{8}{3\pi} = 0{\cdot}85. \quad . \quad (17)$$

For the beams used, D = 0·94 in., thus making the critical span, S, equal to 0·8 in. Substituting this value of $\frac{S}{D}$ in equation (15) the tensile stress at the lower edge becomes

$$\sigma_t = \left(1 - \frac{4}{3\pi\, 0{\cdot}85}\right)\sigma_0$$

$$= \frac{\sigma_0}{2}. \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Therefore, the tensile stress at the lower edge is half of the stress calculated by the simple theory when the span-depth ratio is 0·85.

On substituting numerical values, the reduced stress equations for the longitudinal stresses in the various beams have the form $\sigma_y = mx - b$, where m and b are constants and x is the depth below the upper edge; thus, for the 5-in. span beam, $\sigma_y = 4{,}920x - 2{,}212$ lb. per square inch, and for the 1·0-in. span beam, $\sigma_y = 2{,}260x - 535$ lb. per square inch, both expressions relating to a bending moment of 103·8 lb.-in.

The Transverse Stress Equation.—The basic expression for the transverse stress is given in equation (7). For a constant load P, the equation has the form

$$\sigma_x = Kx - \frac{a}{x},$$

which is represented by the two curves, shown dotted, *viz.*, a straight line, A*u*, and the curve *vw*, both shown in Fig. 16; taken together, these give the resultant curve where $\sigma_x = 0$ for $x = 2c$. For small values of x, the theoretical stress value tends to infinity.

The stress increment per lb. of load applied to a beam of given span is

$$\frac{2}{\pi t}\left(\frac{x}{4c^2} - \frac{1}{x}\right) \text{ lb. per square inch, (19)}$$

and, therefore, the effects of load increase are greatest at and near the upper edge of the beam, and the rate of increase of stress is

$$\frac{P}{2\pi t c^2} + \frac{1}{x^2} \quad \frac{\text{lb. per sq. in.}}{\text{in.}}. \quad (20)$$

Also, $P = \frac{2M}{l}$, where M is the bending moment, therefore, the transverse stress is given by

$$\sigma_x = \frac{4M}{\pi l t}\left(\frac{x}{4c^2} - \frac{1}{x}\right);$$

for a fixed distance x for all beams and for a constant bending moment, M, the stress produced is inversely proportional to the span, i.e., decreasing the span by one half makes the transverse stress twice as large.

On substituting the appropriate numerical values of P, the transverse stress equations for the various beams are reduced to the form $\sigma_x = z\left(mx - \frac{1}{x}\right)$, where z and m are constants; thus, for the 5-in. span beam, $\sigma_x = 197{\cdot}5\left(1{\cdot}13x - \frac{1}{x}\right)$ lb. per square inch and, for the 1·0-in. span beam, $\sigma_x = 986\left(1{\cdot}13x - \frac{1}{x}\right)$ lb. per square inch, again for equal bending moments.

The Maximum Shear-Stress Equation.—The maximum shear stress at any point is $\tau = \frac{\sigma_x - \sigma_y}{2}$ and substitution of the expressions for σ_x and σ_y, and writing in terms of P, gives

$$\tau = \frac{P}{\pi t}\left[\left(\frac{x}{4c^2} - \frac{1}{x}\right) - \frac{3\pi}{4c^3}\left(\frac{l}{2} - \frac{c}{\pi}\right)\left(x - c\right) - \frac{1}{4c}\right],$$

$$. \quad . \quad . \quad (21)$$

and on substituting the values $t = 0{\cdot}268$ in. and $c = 0{\cdot}47$ in.,

$$\tau = P\left(13{\cdot}48lx - 5{\cdot}365x + \frac{1{\cdot}19}{x} - 6{\cdot}35l + 2{\cdot}52\right),$$

$$. \quad . \quad . \quad (22)$$

$$\frac{d\tau}{dx} = P\left(13{\cdot}48l - 5{\cdot}365 - \frac{1{\cdot}19}{x^2}\right),$$

and the maximum shear stress has its minimum value when

$$x = \left(\frac{1{\cdot}19}{13{\cdot}48l - 5{\cdot}365}\right)^{\frac{1}{2}}. \quad . \quad (23)$$

This expression is evaluated in the accompanying Table on page 658.

The minimum value occurs at the lower edge when the span-depth ratio equals 0·915, i.e., when the span is 0·86 in. The variation in τ was shown, as calculated, in Fig. 4, on page 626, and as observed in Fig. 8, on page 628. The respective equations for τ for each beam are obtained by substituting the appropriate values of the load P and the semi-span l, and they have the form $\tau = mx + \frac{n}{x} - b$, where m, n and b are constants. For the 5-in. span, $\tau = 2{,}350x + \frac{98{\cdot}8}{x} - 1{,}104$ lb. per square inch, and, for the 1-in. span, $\tau = 569\,x + \frac{493}{x} - 267$ lb. per square inch, for equal bending moments.

If the value of x obtained from equation (23)

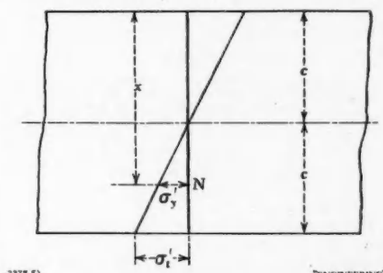


Fig. 14 Stresses produced by bending moments indicated in Fig. 13.

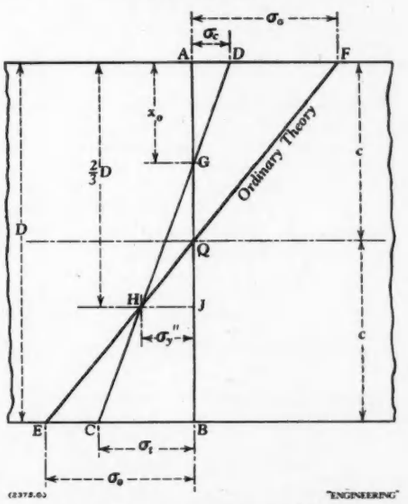


Fig. 15 Longitudinal stresses in the beams of series B.

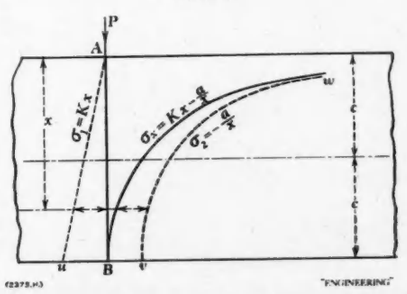


Fig. 16 Correction to the radial stress directly under the load on the beams.

TABLE I. Location of the Minimum Value of τ

Span, in.	5	4	3	2	1·7	1·4	1·0
$\frac{S}{D}$ ratio	5·32	4·26	3·19	2·13	1·81	1·48	1·065
Depth, x in.	0·205	0·235	0·274	0·332	0·442	0·541	0·93
Per cent. of beam depth	21·8	25·0	29·2	35·4	47·1	57·5	99·1

for the minimum value of τ, is substituted in equation (22) and the result equated to zero, the corresponding span-depth ratio may be found. Solving for l when τ is zero gives a value of l equal to 1·98 in., or a span of 3·96 in., corresponding to a span-depth ratio of 4·22. This corresponds to the condition for a single isotropic point in the photoelastic pattern situated at a distance x below the upper edge such that $x = 0{\cdot}238$ in., i.e., at 25·5 per cent. of the depth of the beam, and as was shown in Figs. 4 and 8.

The τ equation for the 5-in. span beam $\left(\frac{S}{D} = 4{\cdot}79\right)$ reduces to

$$\tau = P\left[28{\cdot}38x + \frac{1{\cdot}19}{x} - 13{\cdot}33\right]. \quad (24)$$

For $\tau = 0$,

$$28{\cdot}38x^2 - 13{\cdot}33x + 1{\cdot}19 = 0, \quad (25)$$

for which there are two real roots, namely, $x_1 = 0{\cdot}12$ and $x_2 = 0{\cdot}35$, i.e., at 12·8 per cent. and 37·2 per cent. of the depth, as shown in Figs. 4 and 8. Two isotropic points should therefore appear in the photoelastic pattern for this beam, and this was shown in Fig. 7, on page 627, *ante*.

For a given applied bending moment, there is a point at a common depth for all the beams at which τ has a value common to all the beams. The location of this point and the particular magnitude of the shear stress can be determined by the following argument. If τ is a given function $f(x)$ for one beam, and $\phi(x)$ for a second, these equations are satisfied by a single value of x if

$$F(x) = f(x) - \phi(x) = 0.$$

Using equation (22) and the parametric values $P_1 l_1$, $P_2 l_2$,

$$f(x) = P_1\left(13{\cdot}48\, l_1 x - 5{\cdot}365\, x + \frac{1{\cdot}19}{x} - 6{\cdot}35\, l_1 + 2{\cdot}52\right)$$

$$\phi(x) = P_2\left(13{\cdot}48\, l_2 x - 5{\cdot}365\, x + \frac{1{\cdot}19}{x} - 6{\cdot}35\, l_2 + 2{\cdot}52\right).$$

Since the bending moment is the same for each beam, $P_1 l_1 = P_2 l_2$, therefore, with change of sign,

$$F(x) = 5{\cdot}365\, x(P_1 - P_2) - \frac{1{\cdot}19}{x}(P_1 - P_2) - 2{\cdot}52\,(P_1 - P_2)$$

and, when $F(x) = 0$,

$$5{\cdot}365\, x^2 - 2{\cdot}52\, x - 1{\cdot}19 = 0. \quad (26)$$

This equation has one real root, $x = 0{\cdot}76$ in., corresponding to a depth of 0·81D below the upper edge, and this point of equal stress was shown in Fig. 4, and it is approached approximately in the results of the photoelastic measurements, shown in Fig. 8.

GENERAL CONCLUSIONS

Proper assessment and comparison of the results depend on the general correctness of the calculations and the observations which have been made, and while care has been taken, there may be small errors of observation due to the difficulty of getting good definition in the photo-elastic fringe patterns near the upper and lower edges of the beam. In order to obtain a comparison of the calculated and the photo-elastic results, the differences have been plotted in Fig. 17 against a straight line representing the photo-elastic results. Several interesting characteristics of this comparison can be deduced from these plots and are referred to below.

The first conclusion to be drawn from the investigation is that the Stokes-Wilson theory makes it possible to obtain a very close estimate of the more significant stresses which are produced in short-span beams subjected to simple loading. Nevertheless, while it appears that the theory gives good accuracy at certain points in a beam section, it does not give uniformly good results at all other points of the section. Omitting the undefined conditions at and near the upper edge, there are two points of exact agreement, shown at the cross-over points of the traces in Fig. 17. One of these points is at a distance of approximately 30 per cent. of the depth below the upper edge for six of the beams, and the other point is between a distance of 15 per cent. and 20 per cent. of the depth above the lower edge for all the beams. The best agreement was obtained for the longest beam which has a span-depth ratio of 5·32, and, over all the beams, the differences increase slightly as the span-depth ratio is decreased. Except for the beam with the smallest span-depth ratio, the agreement is very close at the lower edge of the beam where the maximum value of the longitudinal stress occurs. In all cases, the maximum divergences occur at about one-sixth and at about two-thirds of the depth of the section.

Within the upper third of the beam depth, the calculated stresses are less than the photo-elastic results, and within the lower two-thirds of the depth the calculated values are higher. It appears that the Stokes assumption which introduces supplementary stresses reversed in kind and proportional to x—making the transverse stress zero at the lower edge—does not provide adequate correction within the lower two-thirds of the beam. Stress calculations based on the simple bending theory become more and more unsatisfactory as the span-depth ratio is decreased, but the error is increasingly on the side of safety. For example, with a span-depth ratio of 5·32, the calculated longitudinal stress at the lower edge, by the simple theory, would be approximately 8 per cent. greater than the apparent true stress; and for a span-depth ratio of 1·06, the excess of value would be about 40 per cent. greater. For a given bending moment, the longitudinal stresses decrease with a reduction in the ratio of $\frac{S}{D}$, the compressive stress becoming zero for $\frac{S}{D} = 0{\cdot}92$.

The Stokes-Wilson theory makes it possible to calculate the longitudinal compressive stress more correctly at the upper edge and, therefore, a fairly accurate estimate of the permissible limit of the contact stress at the position of load application can be made using the equation $\sigma_x = 2\,\tau_s - \sigma_y$, where σ_y is the calculated longitudinal compressive stress and τ_s is the safe shear stress of the material. This limit can then be compared with the permissible stress that is appropriate to the loading conditions, that is, according to whether the load is steady or fluctuating.

Acknowledgments.—The author is indebted to the Department of Scientific and Industrial Research for the help received, and also to Professor L. J. Kastner, M.A., for the use of the facilities in the Engineering Department of the University College of Swansea.

Our attention has been drawn to the misprint in Part 1, equation (5), on page 625, where the bracket was misplaced; the equation should, of course, have read

$$\frac{3P}{2tc^3}\left(\frac{l}{2} - \frac{c}{\pi}\right) \text{ lb. per sq. in. per in.} \quad (5)$$

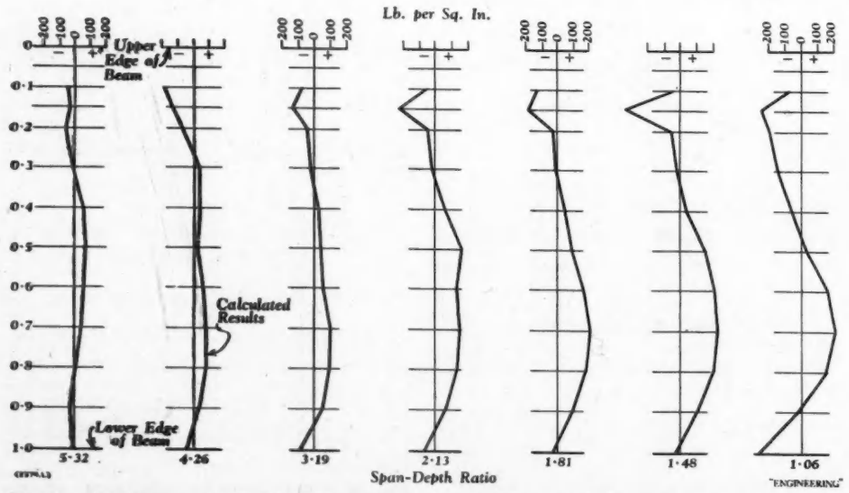


Fig. 17 The differences between the theoretical and observed values of the maximum shear stress.

★ ★ ★

ALL-ALUMINIUM CARS FOR TORONTO SUBWAY

The four cars of all-aluminium construction with the exception of the main bolster, which, as recorded in ENGINEERING (vol. 177, page 342, 1954), are to form part of the rolling stock of the Toronto subway, have now been completed by the Gloucester Railway Carriage and Wagon Company, Limited, Gloucester. They are identical in general design, capacity and power with the 100 steel cars, which were manufactured by the same firm, but weigh 16¼ tons, compared with 22¼ tons. It will therefore be possible to make some useful comparisons of performance and operating costs between the two patterns.

The structural material for these cars was supplied by the Northern Aluminium Company, Limited, Banbury, and the argon arc welding process was used in their construction.

★ ★ ★

SOLDERLESS WIRING CONNECTIONS

The Plessey Company, Limited, Ilford, Essex, have introduced two types of crimp for making solderless joints on electrical contactors. These were evolved primarily for use in the aircraft industry, but have, of course, many other applications.

Fig. 1 The new differential analyser installed at the National Physical Laboratory can provide a solution to any problem which may be expressed in the form of a differential equation.

DIFFERENTIAL ANALYSER

THE N.P.L.'S NEW ANALOGUE COMPUTER FOR SOLVING DIFFERENTIAL EQUATIONS

A new differential analyser, which has taken over five years to build and is believed to be the largest in the world, has just come into use in the National Physical Laboratory, Teddington, Middlesex, where it will be of great assistance to physicists, mathematicians and engineers. The analyser, which is shown in Fig. 1, has been built to solve differential equations and may therefore be used to find the solution to any problem which can be expressed in this form, including many in descriptive geometry, harmonic analysis and synthesis, together with algebraic equations, and certain kinds of partial-differential and integral equations.

Differential equations are continually encountered in all branches of engineering and physics, including diffusion and heat-transfer problems, ballistics, electron optics, statistics, ultrasonics, aircraft design (which involves exceptionally complicated mathematics, especially in connection with supersonic flight), mechanical analysis, and a wide range of applications in electronics and atomic physics. Frequently it is impossible to obtain a formal solution to these equations and, even when such a solution can be obtained, it entails a tedious process by normal methods.

In the past, when a mathematical analysis has given a differential equation, engineers have often had to resort to trial and error for a working solution to their problems; now, however, by making use of the new differential analyser, they can obtain the correct evaluation directly. Results are given to three-figure accuracy which is quite sufficient for practical purposes.

BUSH ANALYSER

A machine for solving differential equations was foreseen in two papers published by Lord Kelvin in 1876, but suitable manufacturing techniques were not then available. In 1930, however, Dr. Vannevar Bush, who later became President Roosevelt's wartime scientific adviser, and is now Chairman of the Carnegie Institute, quite independently designed and built a practical machine at the Massachusetts Institute of Technology and introduced the name: "differential analyser."

A full-size copy of the American machine was built in this country by the Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester 17, for Professor D. R. Hartree, who was then at the University of Manchester and a description of it appeared in ENGINEERING, (vol. 140, page 88, 1935). During the war, it was used to solve problems of many kinds, including those connected with radar, the control of anti-aircraft gunfire, and the design of the atomic bomb. It was transferred to Teddington in 1948 and was used there until the new differential analyser was installed, but its size limited the range of problems that could be handled and the setting up for a new problem involved considerable work.

The differential analyser is an analogue computer, and therefore represents mathematical quantities in terms of distances and shaft rotations, unlike the digital computer, which calculates in terms of actual numbers. The simplest example of an analogue computer is a slide-rule, in which numbers are represented by distances proportional to their logarithms, whereas desk-calculating machines are in effect simple digital computers.

MECHANICAL EQUIVALENTS OF MATHEMATICAL PROCESSES

The differential analyser consists of a number of different mechanical devices, each of which performs a mathematical process. These devices are so coupled that the combination causes the shafts to rotate in such a manner as to represent the quantities which appear in the given differential equations. The machine is actuated by a motor-driven shaft representing the independent variable.

Three principal types of mechanisms are available—integrators, gear trains, and differential gears. The 20 integrators, consist of continuously-variable Gonella gears. Each integrator has two inputs, representing the integrand and variable for integration; the output can thus be the integral of any variable occurring in the problems with respect to any other variable.

Gear trains enable the scale of a quantity to be changed and a varying quantity to be multiplied by a constant, while differential gears are used to add and subtract rotations, in order to obtain the sums or differences of the quantities appearing in a problem; thus the output of any unit may be added to the partial sum of the outputs of preceding elements.

FUNCTION TABLES FOR GRAPHICAL CONVERSIONS

Function tables permit an arbitrary function of any variable to be inserted from the graph and also allow solutions to be obtained in graphical form. This is one of the advantages of the differential analyser over other instruments

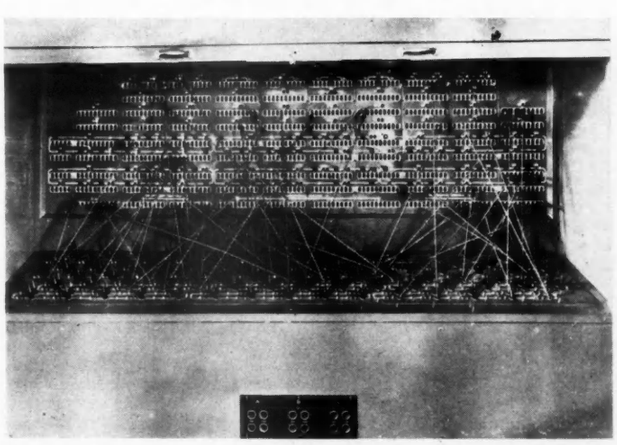


Fig. 2 Setting-up can be completed very rapidly by means of this switchboard which enables the calculating units to be linked by simple plug connections. Up to three problems may be tackled simultaneously.

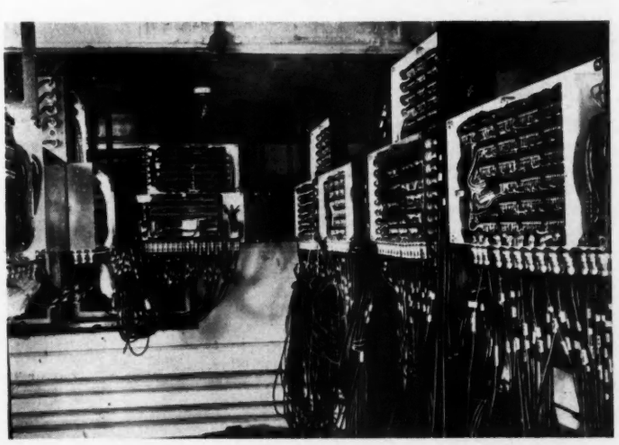


Fig. 3 The analyser, which works on the analogue principle, makes use of servo-mechanisms and is capable of solving equations to which no formal solution exists. Some of the complex wiring is shown here.

and saves considerable time. Any one of six single- and four double-function tables may be used as input tables to convert the function from a graphical representation into rotary motion. As output tables, they are used to record the solution to a problem by converting rotary motion into graphical form. When the tables are used for output conversions, a pen or pencil is set in position by means of two lead screws driven by electric servo-motors, which are coupled to the appropriate units. When they are used for input conversions a graticule is located on the graph by means of handwheels driving the lead screws, and an electric output is obtained from the servo-motors. A photo-electric curve tracer, which follows the line of a graph automatically, will soon be in use.

The special double-function tables enable two functions to be plotted simultaneously against either one abscissa or separate abscissæ. These tables can be used for multiplying two variable quantities, and they also have a specialised use in problems of the type known as hystero-differential equations, such as occur in automatic temperature-control equipment, in which there is a definite time lag between operating the regulator and the occurrence of a corresponding change in the conditions existing in the plant.

SWITCHBOARD COUPLING OF COMPUTING UNITS

The principal disadvantage of earlier analogue computers, such as the small machine previously in use in the National Physical Laboratory, lies in the difficulty of setting up the apparatus to deal with a problem. In machines of this type, the units had to be coupled mechanically and this entailed a major engineering operation that could take several days. In the new differential analyser, these difficulties no longer exist, as all units are coupled by means of servo-mechanisms, which may be connected in any combination through a telephone-type switchboard, which may be seen in Fig. 2; the time taken in setting up a problem is thus reduced to a minimum. On this machine, up to three different problems can be dealt with simultaneously by using separate sections of the analyser. A given problem may be solved in any number of ways; finding the most satisfactory interconnection of the units to represent an equation is as much an art as a science, and still calls for the services of a skilled mathematician.

The design of effective servo-mechanisms to achieve the versatility and precision necessary for an instrument of this kind presented a serious problem; 168 separate motors are used, each with its own amplifier, and for this purpose a total of 1,000 valves are employed. These amplifiers, specially designed by the Metropolitan Vickers Electrical Company, Limited, receive the output from magslips which compare the position of driving and driven shafts, and amplify the output to feed the servo-motors, which produce sufficient torque to drive any unit in the analyser.

PRE-FORMED WIRING SYSTEM AND INSTALLATION

The major task of wiring and inter-connecting the servo-mechanisms and amplifiers with the central plug board was carried out by the Plessey Company, Limited, Vicarage-lane, Ilford, Essex, whose experience in the development of pre-formed wiring systems in the aircraft field enabled them to produce the special cable forms and wiring accessories required. The numerous circuits were linked by means of 73 large junction boxes, and 18,000 ft. of multicore cable, with over 1,700 multi-way plugs and sockets, were used. The installation work, involving approximately 35,000 electrical connections, was carried out by the Strand Electric and Engineering Company, Limited, 29 King-street, London, W.C.2. The complexity of the wiring is indicated by Fig. 3, which shows some of the connections by which various units in the analyser system are linked.

INCREASING THE THRUST OF JET ENGINES

DESIGN PROBLEMS OF AFTER-BURNING

The design and development of after-burning systems for aircraft jet engines, in particular for accelerating aircraft to supersonic speed, were discussed in a lecture entitled "The Development of Re-Heat" given by Mr. J. L. Edwards, combustion research engineer to the de Havilland Engine Company, Limited, before the Royal Aeronautical Society in London on Thursday, October 21. Discussing the attainment of maximum thrust for a given installation, Mr. Edwards said that since at very high temperatures it would be essential to cool the tailpipe stem and nozzle, entailing losses, it was generally accepted that the maximum useful temperature would be about 2,000 deg. K. For this, it was essential to design the tailpipe with the lowest possible Mach number in the combustion zone.

For temperatures above 1,750 deg. K., the tailpipe required a heat shield. The cooling gas flowing between the shield and the tailpipe must be kept out of the combustible range. The shield must be supported so as to allow freedom for expansion in all directions. Although it had been found that ceramic protective coatings did not allow the use of inferior material, they did permit thinner gauges of high-temperature alloys to be used.

There were, Mr. Edwards said, two techniques for injecting fuel after the turbine—by radial spray bars injecting fuel tangentially to circles coaxial with the engine, or by fuel rings coaxial with the flame stabilisers, injecting fuel radially inwards or outwards. For very high injection rates a combination of both methods gave the best spread of fuel throughout the gas stream. The concept of injection upstream of the turbine, advocated by some authorities, was, he considered, fundamentally wrong.

To obtain good combustion, flame stabilisers were necessary to provide a small region where the initial stages of combustion could proceed relatively slowly. Stabilising baffles could be small flat plates or cones, or a grid of circular gutters interconnected in a framework. The latter arrangement was probably as good as any.

Experiments were at present in hand to determine the effect of stabiliser shape on the eddy zone. Information was badly needed on the rate of temperature rise and rate of flame spread for various gas velocities and air/fuel ratios; to obtain preliminary information, a technique had been evolved employing a number of Sintox rods arranged across the flame, the rod temperature gradients being measured by an optical pyrometer.

Ignition could be electrical by high-tension or high-energy spark, or by "streak," where a small quantity of fuel was injected and ignited in the combustion chamber upstream of the turbine. Although simple, the latter system might not be suitable for multi-stage turbines.

A persistent trouble in the development of both after-burning and ram-jet systems was the onset of "screech," a violently destructive high-frequency vibration, the mechanism of which was not understood. It had been observed with the flame stabiliser near the inner cone, and with the diffusing passage arranged such as to cause early break away; with spray bars positioned some distance upstream of the stabiliser; and was more likely with co-planar than with staggered stabilisers. It could be partially suppressed by baffles in the tailpipe and could often be reduced by the inclusion of a heat shield.

SUPERSONIC SPEED

With the requirement for after-burning to accelerate the aircraft to supersonic speed, the need arose for a more comprehensive variable-area propelling nozzle than the two-position clam-shell type nozzle developed for subsonic installations at temperatures up to 1,800 deg. K. There were two possible techniques—an adjustable bullet in the final nozzle whereby the throat area was changed by moving the bullet back or forwards, or an "iris-shutter" arrangement operated by interconnecting linkages and jacks. The latter arrangement was complex, demanded cooling of the final nozzle, and prevented formidable sealing problems; the former also introduced a major cooling and control problem, and was bulky. There appeared to be no easy way.

In an engine with 250 lb. per second mass flow, an after-burning fuel flow of about 10,000 gallons per hour would be required at Mach 1·5 at sea level, and a burner pressure of at least 1,000 lb. per square inch would be required for lighting up at high altitude. Displacement pumps for such quantities were heavy and cumbersome. The centrifugal pump driven by an air turbine was compact and independent of the engine. Disadvantages were the difficulty in producing the fuel pressure except at high speed, the bulk of air ducting necessary, and the low efficiency; 50 per cent. was probably the optimum and the present value was about 30 per cent.

About 400 brake horse-power was required for the pump drive. An overspeed device for protecting the pump should the fuel supply fail was a requirement. Since the pressure ratio across the pump turbine was proportional to the pressure ratio across the engine compressor, the turbo-pump would supply a quantity of fuel very nearly proportional to the mass flow through the engine. Inconsistencies could be adjusted by an automatic after-burning fuel-flow throttle controlled by the turbine outlet temperature.

★ ★ ★

TERMINOLOGY IN INDUSTRY

International Agreement Sought

Delegates from several national standards organisations met in Vienna during October, under the ægis of the International Organisation for Standardisation, to discuss the form in which terminology in the industrial field should be drafted, especially for use in technological glossaries, so as to facilitate the comparison of terms in the different languages. The meeting was attended by representatives from Austria, France, Germany, India, Italy, the United Kingdom, the United States, the U.S.S.R., Yugoslavia, and from seven international organisations.

It is intended that terms used for world trade shall be short and clearly defined, both nationally and internationally, to facilitate translation, even by the non-expert. Dr. L. Hartshorn, of the Department of Scientific and Industrial Research, one of the United Kingdom delegates at the meeting, stated that "The various I.S.O. committees are preparing standard terms in their respective fields in the hope that ultimately what will amount to a series of standardised multilingual vocabularies, covering the whole industrial field, will be available." A start has already been made in this direction, namely, the International Electrotechnical Commission's vocabulary of electrotechnical terms, of which the second edition is now in the course of publication. It gives terms and definitions in English and French, and terms only in five other languages. A separate edition is produced in Russian.

The Vienna meeting was the technical committee's second, its particular task being that of setting down the general principles for the preparation of these glossaries.

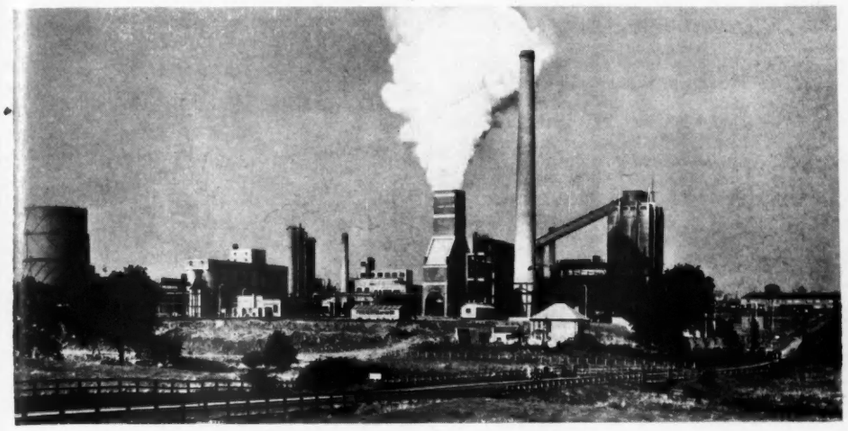


Fig. 1 General view of Fishburn plant, showing from right to left, the coke-oven batteries with their coal bunker and chimney, the coke-quenching tower emitting a "plume" of steam resulting from the spraying of a charge of hot coke, the boiler house and its chimney, the final cooler and two benzol scrubbers, the coal-blending bunkers and the coke-oven gasholder.

THE FISHBURN COKE-OVEN PLANT

GAS FOR THE N.E. COAST GRID

The first of four new coke-producing works which together with existing ovens at Brancepeth and Stella Gill, in County Durham, will be able to supply 40 million cub. ft. of purified gas per day to the Northern Gas Board's North-East Coast gas-grid system has now been placed in commission. This is the National Coal Board's new Fishburn coke-oven plant, a general view of which is shown in Fig. 1; it is situated near Sedgefield, County Durham, some 10 miles north-west of Stockton-on-Tees. It is designed to carbonise daily some 1,000 tons of coal to produce 690 tons of coke, mainly for blast-furnace use, and upwards of 7 million cub. ft. of gas. The other three new coking plants in the Coal Board's construction programme, which is due for completion in 1958, are at Lambton, Murton and Monkton. At Lambton and Murton, 1,000 tons of coal per day will be carbonised, while the existing Monkton plant will be enlarged to enable it to deal with 1,300 tons of coal daily.

The installation at Fishburn, shown in plan in Fig. 2, has been built by the Woodall-Duckham Construction Company, Limited, Woodall-Duckham House, 63-77 Brompton-road, London, S.W.3, as the main contractors and consists of 50 W.-D. Becker combination underjet coke ovens; a coal-handling, blending and crushing plant; a coke-handling and screening plant; a by-product recovery plant of the semi-direct type; a crude benzol plant; a water-cooling and recirculating system and railway sidings and other works.

THE COKE OVENS

The coke ovens, seen from the pusher side and coke side, respectively, in Figs. 3 and 4, are arranged in two adjoining batteries of 25 ovens, each built in line with the coal-storage bunker at one end and the stack at the opposite end. The ovens are each 40 ft. 9¾ in. long, between the doors, 13 ft. high and the average width is 18 in. The capacity of each coke oven is 735 cub. ft., and the two batteries are designed to carbonise daily 1,000 tons of coal containing 9 per cent. of moisture. The ovens are built of silica bricks and the fillings of the regenerators beneath the ovens consist of specially designed fireclay blocks having a large surface area for the exchange of heat. The waste-gas flues are of reinforced concrete lined with firebrick and are built along each side of each battery to connect to the stack at the end of the battery. The stack is 225 ft. high and is lined with firebricks for the first 70 ft. above the waste-gas flue inlet.

HEATING SYSTEM FOR THE COKE OVENS

The ovens are designed for heating either by coke-oven gas when the underjet system is employed or alternatively by producer gas when the producer-gas mains are added in the future. The coke-oven gas underjet system is that at present in use at Fishburn. The heating system consists of a series of vertical flues on each side of each oven connected by cross-over flues over the top of alternate ovens. Beneath each series of vertical flues and connected to them are two regenerators. Each regenerator is divided by a central division wall into two sections, each of half-oven length. With the underjet system employed when coke-oven gas is the heating medium used, half the regenerators, namely, alternate fours in the length of the battery, are utilised to preheat the air. The coke-oven gas is fed from the fuel-gas main through connections carrying the reversing and isolating valves to alternate pairs of cross-header pipes in the basement beneath the battery structure. From the cross-headers, of which there is one beneath each pair of regenerators, pipe connections lead the gas to vertical ducts in the wall between the two regenerators. The gas passes up through the vertical ducts to the base of the vertical heating flues where it meets the pre-heated air and combustion commences. The contour of the flues from the regenerators up which the preheated air travels is such that the air and gas meet with a streamline effect and the burning gas is distributed throughout the length of each vertical flue; combustion takes place along the entire length of an oven wall simultaneously and even heating of the ovens is thus obtained.

The products of combustion are collected from each group of vertical flues and carried over the top of the oven by means of the cross-over flues. From the cross-over flues the waste gases are distributed into, and pass down, the vertical flues on the other side of the oven, exactly opposite the flues up which they have travelled. The waste gases then pass down into the two regenerators beneath, giving up heat in transit. Upon reversal of the valves, which is automatically controlled and occurs at 30-minute intervals, the coke-oven fuel gas is fed through the alternative pairs of cross-header pipes and vertical ducts and the air passes up through the regenerators down which the waste gas had passed previously.

To compensate for the increased oven width on the coke side of the battery, the calibrated nipple in each fuel-gas pipe connection leading to the vertical ducts is increased in area, and the air ports at the bottom of the vertical combustion flues are increased in width throughout the length of the oven. This gradation of orifice and port width ensures that the whole of the charge is evenly carbonised. Particular attention has been paid to the design of the connections to the vertical ducts so that all pipes can be cleaned readily.

CONTROL OF BATTERY OPERATION

The battery control room is situated at the coal-bunker end of the battery of ovens. The

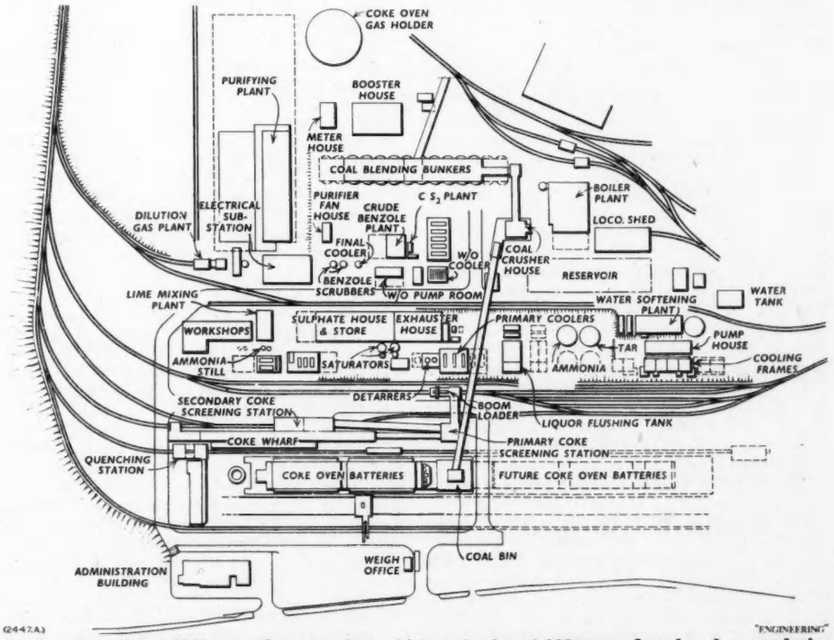


Fig. 2 Plan of the Fishburn coke-oven plant which carbonises 1,000 tons of coal a day, producing nearly 700 tons of furnace coke and over 7 million cub. ft. of gas.

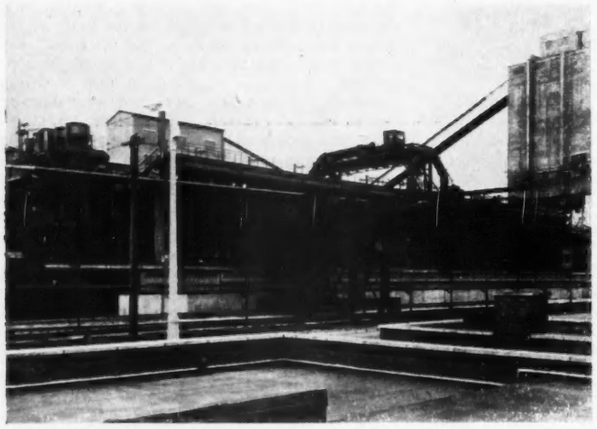


Fig. 3 Pusher side of batteries; in the centre the pusher machine and, above it, the gas collecting-main bridge pipes. On the left, the ovens coal-charging car and on the right the ovens coal bunker. In the background is the secondary coke-screening building.

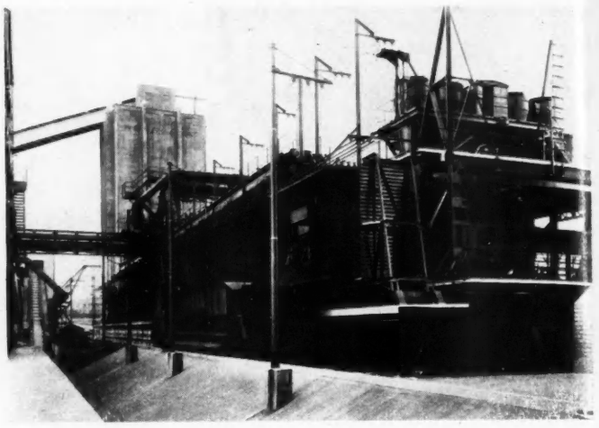


Fig. 4 Coke side of batteries; on the right the coke guide and in the centre the coke-quenching car with its electric locomotive. In the foreground is the inclined coke wharf and on the extreme left the coke-wharf conveyor leading to the primary coke-screening station.

reversing machine, which operates the fuel-gas cocks and the air and waste valves, is placed in this room and is provided with totally-enclosed gearing running in oil. Normally operated by an electric motor, the machine is also provided with a steam-engine standby which can be used in case of a failure of power. The movements of the reversing machine are controlled by an electric clock which can be set to operate the machine at various time intervals. An emergency push-button control is provided; should the clock fail to operate the reversing machine at the predetermined time, an alarm is sounded automatically. Also placed in this room is the Reavell-Askania regulator which automatically controls the pressure of the coke-oven fuel gas.

COAL HANDLING, BLENDING AND CRUSHING

Coal for the coke-oven plant is drawn, in the main, direct from the washery, screens and fine-coal froth-flotation plant of the adjoining Fishburn Colliery, although provision is made for the use of coal brought in from other collieries. A system of belt conveyors from the washery delivers coal of less than ½ in. size at the rate of 330 tons an hour to a series of 20 reinforced-concrete blending and storage bunkers arranged in two rows of ten. Each bunker has a capacity of 200 tons. The range has been designed for extension in the future when the total storage capacity will be increased from 4,000 tons to 5,600 tons. At the top of the bunkers, a reinforced-concrete head house accommodates a reversible 60-in. belt conveyor and two 42-in. shuttle belt conveyors which receive the coal from the washery and deliver it into the bunkers as required. At the bottom of each bunker there is a hoppered outlet provided with a rack-and-pinion operated door to control the discharge of coal on to travelling-belt feeders beneath. A 42-in. belt conveyor, running centrally between the two rows of bunkers, receives the coal from the feeders and delivers it on to another 42-in. inclined belt conveyor. This elevates the coal and delivers it directly into chutes feeding the crushers in a crusher house. The crushers, supplied by British Jeffrey Diamond, Limited, are electrically-driven duplicate swing-hammer pulverisers arranged so that both are in operation simultaneously and are capable of reducing the coal so that 80 per cent. passes through a ¼-in. square-mesh sieve. From the crusher house the coal is taken by a 36-in. inclined belt conveyor to the top of the coke-ovens coal bunker. Here it is received by a 48-in. rotary shuttle belt conveyor which distributes it in the bunker as required. The ovens coal bunker is of reinforced concrete and has a total capacity of 3,000 tons of washed crushed coal. It is approximately 145 ft. high. Twenty discharge gates, arranged in rows of four, are provided in the base of the bunker for delivering the coal into the oven coal-charging car.

OVEN CHARGING

The coal-charging car seen in Figs. 3, 4 and 5 is of the portal type, having an elevated main frame allowing a clear passage between its hoppers for the operatives on the coke-battery top. The car is electrically propelled and runs on rails on the top of the battery. It has four steel hoppers having a total capacity of about 17 tons of coal. Each hopper is fitted with an electrically operated vibrating gear and an adjustable measuring device. Coal is charged into the oven through quadrant gates and mild-steel telescopic dropping sleeves, the mechanism for the latter being interlocked with the travelling gear so that the car cannot be driven with the sleeves down. A weighbridge of 60 tons capacity supplied by Henry Pooley and Sons, Limited, is provided for weighing the coal in the car before charging and it is fitted with a dial indicator and recorder.

COKE PUSHING

When carbonisation is complete, the coke is discharged by a pusher machine supplied by the Wellman Smith Owen Engineering Corporation, Limited, into a coke-quenching car. The pusher machine is shown in Fig. 3 and the coke-quenching car in Fig. 4. The pusher machine, which weighs some 96 tons, runs on a rail track; it levels the charge of coal in the oven, removes and replaces the oven doors on the pusher side and pushes the charge of incandescent coke out of the oven. The pusher machine, on one side of the battery, and the coke guide, on the other side, are connected by a system of interlocks which prevent the operation of the pusher ram until the coke guide, seen in Fig. 4, is opposite the same oven and in position to receive the charge. An electrically-operated door-extracting machine which also hauls the coke guide is provided to remove and replace the doors on the coke side of the ovens. The coke guide, as its name implies, guides and supports the hot coke over the coke side platform into the quenching car.

Two electrically operated clay carriers one on each side of the battery are provided to carry the luting clay to the ovens and to elevate it for placing in position at the oven doors. The clay carriers are equipped with adjustable heat shields for the protection of the operator when the carriers are used as platforms for inspection purposes or for cleaning the door jambs.

COKE DISCHARGING AND QUENCHING

The coke-quenching car into which the hot coke is discharged from an oven is built of steel and is approximately 40 ft. long between the end plates. It is mounted on a structural-steel undercarriage having two four-wheel bogies for running on a standard-gauge track. The floor of the sloping bottom of the car and the end frames are lined with plates of a special cast iron intended to withstand sudden temperature changes. There are two cast-steel side-discharge doors extending the full length of the car, each of which is separately operated by a compressed-air cylinder controlled from the cabin of the electric locomotive hauling the car. The locomotive, supplied by Robert Stephenson and Hawthorns, Limited, is of the four-whee. coupled type and is designed to travel at about 10 miles an hour. It is fitted with an electric-motor driven air compressor and air reservoirs for the operation of the coke-quenching car discharge doors and braking system.

The quenching car with its load of red-hot coke is pushed to the quenching station where a predetermined quantity of water is sprayed on to the coke to quench it. The quenching station is of the recirculation type with a brick windshield and a tower rising 100 ft. above rail level. A 10,000-gallon overhead tank supplies the quenching water to a series of special sprays through a hydraulically-operated quick-opening valve controlled automatically by the quenching car as it enters the station. The surplus water from the quenching operation runs into reinforced-concrete settling sumps from which it is withdrawn for return to the quenching tank by two electrically-operated centrifugal pumps. Each has a capacity of 30,000 gallons of water per hour and one acts as a standby to the other. They are operated automatically by a float in the overhead quenching tank. A hoist and grab travelling on an overhead track recovers the coke breeze from the settling sump and delivers it directly into railway wagons.

COKE HANDLING AND SCREENING

After quenching, the coke car is run back to the coke wharf, seen in the foreground in Fig. 4, and the coke is discharged. The coke wharf is 160 ft. in length and is of reinforced-concrete construction. It is surfaced with Accrington Norri-ware bricks laid on edge. The cooled coke is fed through hand-operated regulating gates on to a 36-in. belt conveyor (seen on the extreme left in Fig. 4) which delivers the coke to the single-deck primary vibrating coke screens separating out the pieces above 2½ in. This has a capacity of 75 tons of run-of-oven coke per hour. The oversize coke from the primary screen is either delivered into railway wagons or fed into a coke-cutting machine and reduced in size to less than 1 in.

The undersize coke from the primary screen and the cut coke when the cutter is in use are

Fig. 5 Top of batteries showing the ascension pipes, the gas collecting-main bridge pipes and, in the distance, the portal-type coal-charging car. Gates controlling the coal discharge from the ovens bunker to the charging car are seen above.

delivered by means of a 36-in. belt conveyor to the secondary coke-screening station. Here it is screened into six sizes, namely: 2½ in. to 1½ in.; 1½ in. to 1 in.; 1 in. to ¾ in.; ¾ in. to ⅝ in.; ⅝ in. to ⅜ in.; and ⅜ in. to 0 in. Each of the six hoppers into which the coke is delivered has a storage capacity of 30 tons and can discharge its contents either into rail wagons or road lorries.

GAS-COLLECTING SYSTEM

We now return to the coke ovens to follow the path of the crude gas produced. This leaves the ovens through vertical ascension pipes at both the pusher side and the coke side and passes into horizontal gas-collecting mains running on both sides of the batteries. Two bridge pipes, one for each battery, span the batteries at their adjacent ends and connect the pusher and coke-side collecting mains. From the centre of each bridge pipe there is an offtake main and these two offtake mains are joined into a common suction main spanning the coke quenching-car track and terminating at a downcomer which takes the gas into primary coolers.

Liquor-flushing sprays are provided in the cast-iron return bends of the crude-gas ascension pipes and in the collecting mains, while four pitch traps are provided to serve the collecting mains. The return flushing liquor from the coke-side collecting mains, and the accompanying heavy condensates from the gas, flow along the suction main and downcomer to a liquor-flushing tank. The liquor and condensates from the pitch traps on the pusher-side collecting mains flow through a gravity pipeline to the liquor-flushing tank.

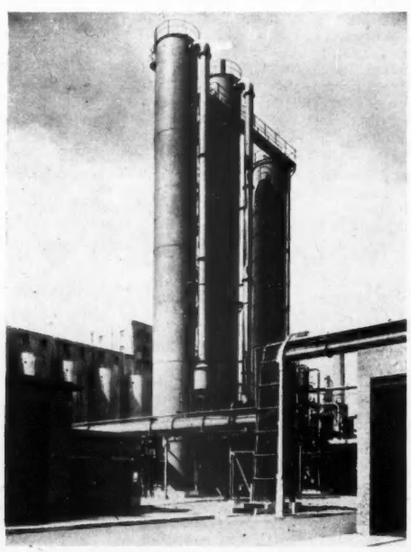


Fig. 6 The two benzol scrubbers on the left and the final cooler on the right. On the extreme right is the crude-benzol plant. In the background are the coal-blending bunkers.

GAS COOLING AND TAR EXTRACTION

The primary coolers into which the gas passes from the ovens are of the vertical tubular water-cooled type standing on an elevated reinforced-concrete structure. Three coolers are provided; two of them are normally in operation with one as a standby, and each cooler is provided with two seal pots to receive the condensed tar and ammoniacal liquor.

From the primary coolers the gas is passed to electro-detarrers by exhausters. There are two of these, one of which is normally in operation, the other serving as a standby. The exhausters, supplied by the British Thomson-Houston Company, Limited, are turbine-driven centrifugal machines of the axial-inlet radial-flow type capable of delivering all the gas produced against a normal back pressure of 2½ lb. per square inch. Each exhauster is direct coupled to a steam turbine operating with steam at a pressure of 150 lb. per square inch and exhausting against a back pressure of 15 lb. per square inch. A regulator controls the hydraulically-operated steam throttle valves and maintains a constant vacuum in the gas inlet.

The two electro-detarrers have been supplied by Whessoe Limited; they are 9 ft. in diameter and are of the vertical-tube suspended-wire electrode type. Normally both are in operation but, in an emergency, either is capable of handling the normal gas load without loss of efficiency. The detarrers are situated on the roof of a building containing the two transformer rectifier sets for operating the detarrers.

AMMONIA SATURATORS AND STILL, AND ACID SEPARATORS

From the electro-detarrers the gas passes through a re-heater before entering the ammonia saturators, two of which, standing in the open, are provided, one acting as a standby. In the saturators the ammonia contained in the gas reacts with dilute sulphuric acid and this results in the formation of ammonium sulphate. The saturators, which are designed to produce a large-crystal sulphate salt, are 12 ft. 6 in. in diameter and are supported on structural-steel columns. They are of welded steel construction and lead lined and finally lined with tiles. The gas enters by way of cracker pipes and bubbles through the sulphuric acid contained in the saturators and passes on to two separators where traces of entrained acid are removed. The cracker pipes and the continuous overflow weirs and piping of the saturators are all constructed of Monel metal.

The ammonia-liquor condensate from the primary coolers is distilled in a still standing in the open and the ammonia gas conveyed by pipeline to the inlet to the saturators. A lime chamber for mixing lime water with the ammonia liquor, when this is considered desirable, is also provided.

Each saturator is equipped with a bronze salt ejector for discharging the ammonium sulphate produced through a lead and tile-lined sulphate pot to stainless-steel crystal separators. The sulphate passes from either of the two separators provided to centrifugal driers and the separated mother liquor is returned to the saturators. Two electrically driven two-stage air compressors supply the compressed air for use in the sulphate ejectors. The ammonium sulphate is washed free from acid and finally dried by hot air in a rotary louvre machine having a capacity of 30 tons of the salt per day. This machine has been supplied by Dunford and Elliott (Sheffield) Limited. The sulphate is then automatically run into bags which are loaded by a conveyor either into road vehicles or railway wagons.

FINAL COOLER, BENZOL SCRUBBERS AND GASHOLDER

After leaving the saturators and acid separators, the gas passes through the 80-ft. high final cooler prior to the extraction of the benzol. The cooler is seen on the right in Fig. 6; it is of the direct type and contains a number of sections of timber grids. The base of the cooler is provided with a tar leg through which the cooling water is passed for the removal of the naphthalene it contains. The tar section is steam heated. From the final cooler the gas passes through a water separator to the two benzol scrubbers, seen on the left in Fig. 6, wherein it travels in series in an upward direction meeting a downward travelling stream of wash oil which absorbs the crude benzol. The scrubbers are 95 ft. in height and are provided with wooden hurdles and an oil-distributing device. After leaving the scrubbers the gas passes through an oil separator to the gasholder, provided by Whessoe Limited. This has a storage capacity of 500,000 cub. ft. of coke-oven gas. It is of welded steel construction and of the three-lift spiral-guided type.

BENZOL RECOVERY

The wash oil from the scrubbers, enriched with the benzol removed from the coke-oven gas, is passed through two vertical-tube vapour-to-oil heat exchangers. In these heat is transferred from the crude benzol vapour leaving the still to the benzolised wash oil. The enriched wash oil is then steam heated and enters the cast-iron wash-oil still. This, which is 5 ft. in diameter, deals with the whole of the wash oil and has a series of 14 trays where the crude benzol is removed by intimate contact with steam. The crude benzol vapour passes from the still through the vapour-to-oil heat exchanger to an open-type crude benzol cooler. From this the crude benzol passes through a separator and either to storage or, through a filter, to the carbon disulphide cast-iron still. In this the CS_2 is removed from the benzol which is cooled and passed to storage.

The CS_2-free benzol is converted into pure products at the National Coal Board's various refineries. The CS_2 from the still passes through a condenser to a decanter from which a portion is returned to the reflux chamber of the still and the remainder flows into a storage tank.

GAS PRODUCER AND DRY FINAL PURIFIERS

The purpose of a gas producer, installed by Gibbons-Heurtey Limited, Dudley, is to provide clean producer gas to dilute the high calorific value of the rich coke-oven gas produced at Fishburn down to town-gas requirements, namely, to the Gas Board's standard calorific value of 475 B.Th.U. per cubic foot. The fuel used in the producer consists of coke nuts, either of ¾ in. to 1½ in. or of 1 in. to 2 in. sizes. It produces 41,600 cub. ft. of gas per hour at a pressure of 20 in. water gauge at the final scrubber outlet.

The final treatment given to the mixed coke-oven gas and producer gas is to remove the hydrogen sulphide present. This is accomplished by passing the gas into purifiers, and, to maintain the flow of gas through the purifiers, two Rateau star-type turbo-booster fans have been installed. One fan is normally in operation, the second serving as a standby. Each fan has a capacity of 300,000 cub. ft. per hour measured at 60 deg. F., and 30 in. of mercury, and is capable of delivering the gas at an outlet pressure of +30 in. water gauge.

The purifiers, a general view of which is shown

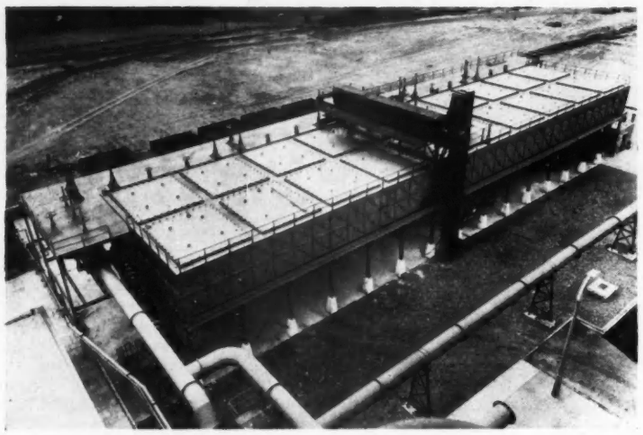


Fig. 7 Dry iron-oxide final purification plant for removal of hydrogen sulphide from the gas, showing travelling oxide-handling and cover-lifting apparatus.

in Fig. 7, were designed, constructed and erected by Newton, Chambers and Company, Limited, Thorncliffe, near Sheffield, and have a capacity of 7 million cub. ft. of gas per day. The purifying material employed is hydrated oxide of iron which converts the hydrogen sulphide into iron sulphide. The installation consists of five cast-iron purifiers, each 40 ft. long by 35 ft. wide by 10 ft. deep, carried on a mild-steel sub-structure. Each purifier contains two layers of oxide 3 ft. 6 in. deep and the gas to be purified enters between the two oxide layers. A primary steam-heated gas heater is installed in the main inlet and a secondary heater at the inlet to each box. Four mild-steel covers are provided to each purifier.

For discharging the oxide there are four oxide chutes to each purifier. The charging of the oxide is carried out by means of a combined oxide-handling plant and cover-lifting apparatus manufactured by Robert Dempster and Company, Limited, Elland, Yorkshire, and seen in Fig. 7. This plant consists of a vertical belt and bucket elevator with its hopper just above ground level and a flat rubber and canvas belt conveyor for distributing the oxide in the purifiers.

The whole of the installation runs on rails mounted on the purifier structure. The oxide-handling plant is designed for a discharge rate of 20 tons an hour and a charging rate of 40 tons an hour. Air for the revivification of the oxide *in situ* is provided by two Keith-Blackman steel-plate turbo-blowers, each having a capacity of 14,000 cub. ft. of free air an hour, one machine being in operation at any one time, the other acting as a standby. When the oxide mass contains a high proportion of iron sulphide it can no longer be revivified and the material is sold to manufacturers of sulphuric acid.

GAS COMPRESSORS AND BOOSTERS

As has been stated at the outset of this article, the Fishburn coke-oven plant is designed to supply some 7 million cub. ft. of gas to Stockton Gasworks, and this is done through an 18-in. diameter main approximately 10½ miles long. In order to accomplish this, provision has been made for compressing the gas to any required pressure up to 30 lb. per square inch.

To meet these conditions, three gas compressors have been installed by Belliss and Morcom Limited, Birmingham. Each of these compressors is capable of taking in and compressing 5·3 million cub. ft. of purified gas per 24 hours to a pressure of 30 lb. per square inch. When compressing to lower pressures, the quantity of gas dealt with is, of course, increased. Two of the compressors are driven by Mather and Platt synchronous motors running at a constant speed of 333 r.p.m. and direct coupled to the compressor. The motors, however, are installed in a separate house from the compressors in the interests of safety. The third compressor is driven by a Belliss and Morcom steam engine fitted with variable-speed gear. This is of the two-crank compound design, supplied with steam at a pressure of 150 lb. per square inch gauge. The engine exhausts against a back pressure of 15 lb. per square inch, and this exhaust is afterwards used for process work elsewhere on the plant.

The compressors are of the two-crank, two-cylinder, double acting single-stage type, totally enclosed and fitted with forced lubrication to all working parts. The cylinders are water-cooled and the gas is boosted into the main through after coolers.

As it is not possible with a constant-speed motor to vary the speed of the motor-driven compressors, these machines are fitted with special relay-operated controls which, if required, will vary the gas quantity entering the compressors according to the gas demand. Generally-speaking, however, it is anticipated that one motor-driven set will run continuously at full load and the speed variation to meet the fluctuating load will be done by the steam-engine driven set. The third compressor, with its motor drive, will be a standby plant.

BOILER PLANT

Installed in a separate boiler house are three water-tube boilers supplied by Daniel Adamson and Company, Limited, Dukinfield. The rated capacity of each boiler is 20,000 lb. per hour at normal load and 25,000 lb. per hour at maximum load, at a steam pressure, at the superheater outlet valve, of 180 lb. per square inch gauge and a steam temperature at the superheater outlet valve, at maximum load, of 540 deg. F. The boilers are designed for an efficiency of 78 per cent. at normal load. They are of the bi-drum pattern, namely, they are equipped with one upper steam and water drum and one lower water drum.

The boilers are arranged for coal and coke firing on the "sandwich" system and there are also coke-oven gas burners for use with, or instead of, coal and coke firing. The coal and coke receiving hopper is situated outside the boiler house in a position which allows direct unloading of coal and coke from railway wagons into the hopper. A skip hoist discharges the fuel on to an overhead moving-belt conveyor. Each boiler is provided with a double bunker providing separate compartments for coal and coke and into these the fuel is discharged from the overhead moving-belt conveyor by means of a travelling tipping gear. From the bottom of these bunkers, oscillating fuel chutes take the coal and coke to class "L" travelling-grate stokers supplied by International Combustion Limited. At the opposite end of the stoker, the ash is discharged through a hopper on to a submerged ash-conveyor belt. The belt travels to an ash bunker built over a rail track.

Water for the boilers and coolers is pumped from a seam at Fishburn Colliery into an intermediate storage reservoir. It is of high hardness, with a tendency to encrustation, and is treated in a John Thompson-Kennicott cold-process type water-softening plant having a capacity of 20,000 gallons per hour.

By way of conclusion, average figures for throughput and production for the month of August, 1954, may be of interest.

Coal carbonised	1,030 tons a day
Moisture content	10 per cent.
Dry coal carbonised	927 tons a day
Oven charge	16·92 tons of wet coal
Operating cycle	19 hours 43 min.
Underfiring	1,065 B.Th.U. per wet lb.
Coke (wet)—	
Large coke	565·0 tons per day
2½ in.–1½ in.	47·0 „ „
1½ in.–1 in.	22·2 „ „
1 in.–¾ in.	13·2 „ „
¾ in.–½ in.	5·5 „ „
½ in.–⅜ in.	3·9 „ „
Breeze	31·0 „ „
	687·8 „ „
Sulphate of ammonia	11·1 tons a day
Lb. sulphate per ton dry coal	26·85
Crude benzol	3,100 galls. a day
Crude benzol galls. per ton of dry coal	3·34
Tar	45 tons a day
Surplus gas	7·3 million cu. ft. a day

★ ★ ★

LAUNCHES AND TRIAL TRIPS

M.S. "TROMAAS."—Single-screw oil tanker, built and engined by Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, Sweden, for Mr. Arnt J. Mörland, Arendal, Norway. Main dimensions: 526 ft. between perpendiculars by 69 ft. 9 in. by 39 ft. 3 in.; deadweight capacity, about 18,125 tons on a draught of 30 ft. 4¾ in.; oil-cargo capacity, 854,664 cub. ft.; dry-cargo capacity, 30,800 cub. ft. B. and W. nine-cylinder single-acting two-stroke Diesel engine, developing 9,000 i.h.p. Speed, 15½ knots, fully loaded. Delivered, October 14.

M.S. "ST. ROGNVALD."—Single-screw coasting vessel for the carriage of twelve passengers, livestock, and general cargo, between Leith, Aberdeen and the Orkney and Shetland Islands, built by Alexander Hall & Co. Ltd., Aberdeen, for the North of Scotland, Orkney and Shetland Shipping Co., Ltd., Aberdeen. Main dimensions: 244 ft. overall by 39 ft. by 21 ft. 6 in. to shelter deck. Denny-Sulzer seven-cylinder two-stroke trunk-piston oil engine, developing 2,100 b.h.p., constructed by William Denny and Brothers, Ltd., Dumbarton. Service speed, 13 knots. Launch, October 14.

S.S. "KINGSTON TURQUOISE."—Single-screw trawler, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for the Kingston Steam Trawling Co., Ltd., Hull. Second vessel of an order for three. Main dimensions: 189 ft. by 32 ft. by 17 ft. 6 in.; gross tonnage, about 800; fishroom capacity, 16,940 cub. ft. Triple-expansion steam engine and one oil-fired boiler, supplied and installed by Charles D. Holmes & Co., Ltd., Hull. Launch, October 15.

SHIP No. 496.—Grain-elevating pontoon, built by the Goole Shipbuilding and Repairing Co., Ltd., Goole, for Ministry of Transport and Civil Aviation, London, W.1. Main dimensions: 87 ft. by 37 ft. 6 in. by 15 ft. Launch, October 15.

M.S. "MARINIA."—Single-screw ocean-going tug, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, for the Overseas Towage and Salvage Co., Ltd., London, E.C.3. Main dimensions: 120 ft. 9 in. by 28 ft. 6 in. by 13 ft. 9 in. Monarch-type 20-ton tow hook fitted on top of the tow-line winch house. Six-cylinder single-acting two-stroke Diesel engine, developing 960 b.h.p. at 250 r.p.m., constructed by British Polar Engines, Ltd., Glasgow, and installed by Amos and Smith Ltd., Hull. Launch, October 16.

M.S. "BEECHMORE."—Single-screw vessel, to carry citrus fruits and general cargo, and with accommodation for twelve passengers, built by the Burntisland Shipbuilding Co., Ltd., Burntisland, Fife, for the Mediterranean trade of Johnston Warren Lines Ltd. (Managers: Furness, Withy & Co., Ltd.), Liverpool. Main dimensions: 345 ft. between perpendiculars by 52 ft. 7 in. by 32 ft. 4 in. to shelter deck; deadweight capacity, 4,900 tons on a draught of 21 ft. 9⅛ in. Hawthorn-Doxford four-cylinder opposed-piston Diesel engine, arranged to burn heavy-fuel oil and developing 3,300 b.h.p., constructed by Hawthorn Leslie (Engineers) Ltd., Newcastle-upon-Tyne, and installed by the shipbuilders. Trial trip, October 20.

PRESTRESSED-CONCRETE ARCHED SILO

THREE-PINNED FRAMES COVERED WITH PRE-CAST CONCRETE PLANKS

An unusual building consisting of prestressed-concrete three-pinned arches covered with pre-cast concrete planks has recently been completed for the bulk storage of dumped ammonium sulphate by the South East Gas Board at Phœnix Wharf, Greenwich. The general form of the building frame is shown in Fig. 1 below, and the details in the adjacent Fig. 2. Various chemical by-products of gas production are handled at the works and an extensive scheme of reconstruction, which is now nearing completion, has included a combined structure for the storage, handling and bagging of the sulphate of ammonia. The adjacent buildings to the store—which is the main subject of this article—are of normal reinforced concrete.

The site is located on dumped fill overlying recent alluvial deposits which in turn are above a dense bed of flooded-plain gravel and blue London clay. The whole building comprises the store, which is 168 ft. long and 96 ft. wide, and the bagging house which is 108 ft. wide by 60 ft. long. The floors of these two buildings at ground level are continuous and consist of transverse tie beams and slabs with a granolithic finish for the store, and of a conventional arrangement of pile caps, beams and slabs for the bagging house. As the foundation loads could not be borne by the alluvial deposits, piles were driven into the top of the gravel beds which are 18 ft. thick and 20 ft. below the surface. A total of 389 Franki piles were sunk and cast *in situ*, of which 213 support the floor of the sulphate store.

The store has been built with battered reinforced-concrete retaining walls, 17 ft. 6 in. high, which are shown in detail in Fig. 2, along two sides. These walls were cast *in situ* with buttresses at 8-ft. centres and opposing pairs of buttresses in the facing walls form the abutments for the pre-cast prestressed-concrete three-pin arches which have spans of 86 ft. 6 in. and a rise of 48 ft. 6 in. Each arch consists of a pair of ribs, 12 in. wide and varying in depth from 21 in. at the ends to 33 in. at the point of maximum bending moment; each rib is 66 ft. long and weighs approximately 13 tons.

The ribs were pre-cast on site on a purpose-made "whale-back" casting bed designed to take six ribs simultaneously, though only one pair of side shutters was provided. At both ends of each rib are factory-made blocks which incorporate the hinges—rockers at the abutment springings and knife-edges at the crown, both hinges being of malleable cast iron.

Fig. 1 To be used for the storage of bulk ammonium sulphate, the silo has been constructed from three-pinned prestressed-concrete arches springing from buttressed retaining walls and covered with pre-cast concrete planks.

Suitable ducts were cast in the end block during manufacture and, prior to placing the concrete for the ribs, the blocks were correcty aligned on the casting bed and the "Macalloy" prestressing rods threaded through the blocks, the central length of the rod being sheathed with "Kopex" tubes to prevent bond. The mix was designed to develop 4,500 lb. per square inch at 10 days, using proportions of 1:1·4:2·8 by weight and a water/cement ratio of 0·38. A sulphate-resistant cement and a ¾-in. maximum aggregate were used.

It had been intended to cast and stress six ribs in a fortnight, but the contractors were able to reach a rate of five ribs in a week, stressing being completed six days after casting. The Lee-McCall system of prestressing was adopted and the principal reinforcement consists of a 1⅛-in. dia. Macalloy bar in two parts, one 62 ft. long, the other 5 ft. 0⅝ in. The length of the rib was too long for the greatest lengths of bar available and couplers had therefore to be incorporated in the design; these couplers have been located in the abutment block of the rib, which had to be provided with an otherwise oversize duct sufficient to house the coupler. After stressing the ribs were transferred to a special storage area laid out on the floor of the store from where they were slung into position using a derrick with a 117-ft. jib.

Concrete planks, factory made and pre-tensioned in separate moulds, form the roof covering. Each plank is 7 ft. 6 in. long, 12 in. wide and 3 in. thick. Steel hoops projected from the ends of each plank and these hoops fitted over protruding stirrups along the back of each rib; ordinary steel reinforcement was then threaded through the stirrups and over the hoops to hold the planks in position, the 6-in. gap between the ends of the planks being concreted in using the hoops and stirrups as reinforcement.

At the apex of the arch two crown slabs span between successive ribs and rest on corbels cast on the side of each rib. The slabs are tied to the ribs by seven cables stressed by the Gifford-Udall-CCL system, the cables spanning from outside to outside of adjacent ribs; suitable chases in the sides of the rib gave access to the trailing end of the cables, all stressing being done from the leading end. The crown slabs also served to form a tie between the arches until the plank in-filling was completed. A 1-in. gap was left along the ridge between pairs of crown slabs to preserve the pin action of the arch. An exterior waterproof finish has been laid over the roof consisting of two layers of "Cromastic Lastic" with a dusting of white sea shell chips applied to the top coat before it had dried to lessen the otherwise sombre appearance.

The ends of the storage building have been formed by a reinforced-concrete frame with brick panelling. At one end the wall incorporates a reinforced-concrete retaining wall, 17 ft. 6 in. high, which supports the structure for the pneumatic-handling plant to be used for conveying the sulphate from the adjoining production building. The other gable forms part of the end wall of the bagging house which is to be equipped with screening, conveying, weighing and sack-sealing machinery.

The design of the store, as well as of the bagging house, has been prepared by the central construction department of the Gas Board working in conjunction with "Twisteel" Reinforcement Limited, 43 Upper Grosvenor-street, London, W.1, who prepared the detailed drawings. The principal contractors were the Demolition and Construction Company, Limited, 3 St. James's-square, London, S.W.1. The pre-cast end blocks and the crown slabs were made by the Liverpool Artificial Stone Company, Limited, Picton-road, Wavertree, Liverpool 15, and Anglian Building Products Limited, Atlas Works, Lenwade, Norwich, respectively.

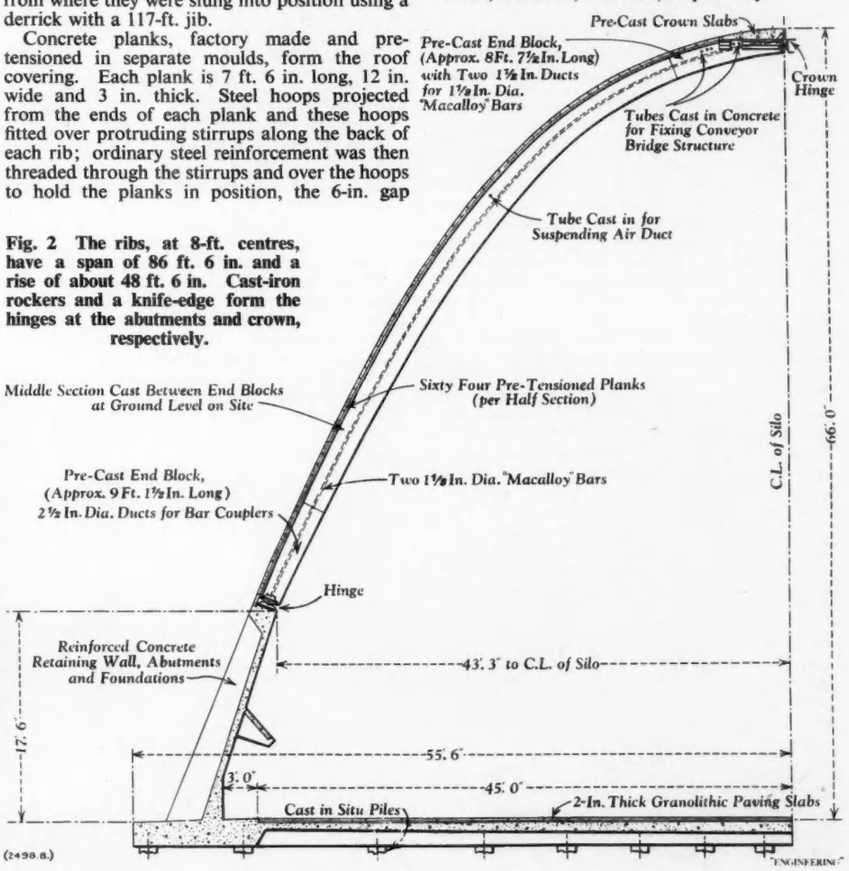

Pre-Cast Crown Slabs
Pre-Cast End Block, (Approx. 8Ft. 7½In. Long) with Two 1⅛ In. Ducts for 1⅛ In. Dia. "Macalloy" Bars
Crown Hinge
Tubes Cast in Concrete for Fixing Conveyor Bridge Structure
Tube Cast in for Suspending Air Duct
Middle Section Cast Between End Blocks at Ground Level on Site
Sixty Four Pre-Tensioned Planks (per Half Section)
Pre-Cast End Block, (Approx. 9 Ft. 1½In. Long) 2½ In. Dia. Ducts for Bar Couplers
Two 1⅛ In. Dia. "Macalloy" Bars
C.L. of Silo
66. 0"
Hinge
Reinforced Concrete Retaining Wall, Abutments and Foundations
43. 3" to C.L. of Silo
17. 6"
55. 6"
3. 0"
45. 0"
Cast in Situ Piles
2-In. Thick Granolithic Paving Slabs
(2498.8.)
"ENGINEERING"

Fig. 2 The ribs, at 8-ft. centres, have a span of 86 ft. 6 in. and a rise of about 48 ft. 6 in. Cast-iron rockers and a knife-edge form the hinges at the abutments and crown, respectively.

THE PUBLIC WORKS CONGRESS AND EXHIBITION

SOME ROAD-BUILDING PLANT AT OLYMPIA

Continued from page 635

This year's Public Works and Municipal Services Congress and Exhibition was opened at Olympia last Monday, November 15, and is remaining open until tomorrow, Saturday, November 20. We continue below our brief descriptions of some of the exhibits displayed there.

ASPHALT MIXING PLANT

The largest machine that was displayed on the stand of Frederick Parker, Limited, Leicester, is the " Starmix " No. 8 asphalt and bituminous mixing plant, illustrated in Fig. 7, opposite, and described below. A smaller mixing plant, with an hourly capacity of between 5 and 10 tons, the " Spot-Mix " was also being displayed; this latter machine, introduced about a year ago, has been designed specially for road patching and laying car parks, playgrounds, tennis courts, etc.

The " Starmix " is a single-unit plant of medium capacity, 12 to 25 short tons per hour of mixed asphalt according to the moisture content of the aggregate and the temperature of the final mix, and fully mobile for moving from site to site quickly, easily and economically. With this latter point in mind, the plant is normally mounted (as illustrated) on pneumatic tyres. For discharge into lorries, the hoist skip travels on a runway below the paddle mixer and has a ground clearance of 7 ft. 0 in. Lifting beams and tackle are available so that the drier can be taken off as a unit to be carried separately on a lorry, if a low travelling height is necessary; the side platforms can be raised to reduce the travelling width, and the dust collector can also be folded down. In this way a minimum travelling height of 12 ft. 0 in. and a width of 9 ft. 0 in. are obtainable. Where such high mobility is not required, the " Starmix " can be supplied mounted on steel wheels or as a stationary plant raised on jacking legs.

Only one aggregate elevator has been fitted in the plant, thereafter all the material falls by gravity to the paddle mixer (or pug-mill). The elevator receives the stone from a 2½-cub. yd. hopper and feeder which ensures a controlled rate of feed to the drier and hence a regular output at a constant temperature. At the top of the elevator the aggregate passes into the drier through a feed ring fitted with built-in scoops which serve to distribute aggregate evenly.

The drying cylinder itself is 14 ft. long and 3 ft. in diameter, and inside is fitted with an arrangement of " lifters " which produce a dense cascade of material falling through the hot gases from the burner. At the end of the cylinder the stone is separated into three sizes by concentric conical screens which are kept hot by radiating heat from the drier. The dust in the drying cylinder is drawn-off by a " paddle-rotor " type fan and is passed to a cyclone dust collector; the dust can then put into the filler or sand bin.

Burner equipment, temperature controls and bitumen pump are of conventional pattern, and the plant as a whole is driven by a 32-h.p. Diesel engine. A 500-gallon bitumen kettle, heated by two Diesel-oil burners, can be incorporated in the plant if desired.

Also on this stand, one of the largest in the Exhibition, were the " Rocksizer " crusher and the " Stonesizer " granulator, together with the company's newly-introduced " Cascade " stone, gravel and sand washer, a mobile machine with a capacity of between 10 and 15 tons per hour.

HYDRAULIC LOADER

A machine recently introduced into the Muir-Hill range that is manufactured by E. Boydell and Company, Limited, Old Trafford, Manchester, is the 2-WL hydraulic loader which was on the company's stand. This machine is designed to cover the handling of a very wide range of materials; it is fitted with a 1-cub. yd. (or 25-cwt.) bucket as standard, but two larger and one smaller buckets are also available. The machine is shown in Fig. 8.

The construction incorporates the Muir-Hill three-point pivoted suspension system which provides articulation between front and back wheels. The design of the jib and frame allows the load to be taken by the main frame and not by the hydraulic rams when the bucket is being forced into the spoil. Double-acting rams are used and the fluid is " full-flow " filtered. The controls are centrally grouped around the steering column, together with the combined clutch and brake pedal and the twin gear levers. There are six forward and two reverse speeds provided by the constant-mesh gearbox. The Diesel engine develops 42 brake horse-power at 1,750 r.p.m. and a maximum torque of 140 lb.-ft. at 1,100 r.p.m. The loader has a maximum forward reach of approximately 3 ft. 8 in. and an under-bucket clearance of 11 ft. 2 in. The unladen weight is 4 tons 16 cwt. A wide range of standard accessories is available.

PORTABLE AIR COMPRESSOR

Among the variety of quarry and mining machinery displayed on the stand of the Atlas Diesel Company, Limited, Wembley, Middlesex, there was a new portable compressor, the KE6MV, shown in Fig. 9, herewith. Designed for a wide field of industrial applications, it is particularly applicable to the smaller civil-engineering contract and for building work, having a free-air output of 37 cub. ft. per minute at 80 lb. per square inch.

The compressor consists of an " Atlas " standard air-cooled compressor with two single-stage cylinders in V-form, an air-intake filter and an unloader regulator, and it is the first machine of its type to be driven by the new Armstrong Siddeley single-cylinder air-cooled Diesel engine. This engine has a maximum output of 11·6 h.p. at 1,610 r.p.m., and the drive is transmitted to the compressor by four A-type V-ropes working off the engine pulley which is itself coupled to the flywheel by a centrifugal clutch so as to ease starting.

As may be seen from the illustration, the compressors and engine are mounted above two cylindrical air receivers which together form the chassis framework. The undercarriage consists of a single axle on semi-elliptical springing, two pneumatic-tyred road wheels, mudguards, a steel drawbar with a steady leg and spring-loaded towing eye as well as parking and over-run brakes. To comply with legal requirements in respect to road travelling at speeds up to 20 m.p.h., " T "-plates have been fitted; alternatively, the compressor, which weighs only 12 cwt., is easily loaded on to lorries for conveyance over longer distances. Overall dimensions of the unit are: length, 7 ft. 7 in.; width, 3 ft. 11 in.; height, 4 ft. 9 in.

Other equipment on this stand included rock drills and air hoists, the latter incorporating a new Atlas radial air motor. There was also a display of the full range of the company's paint-spraying equipment, including a paint preheater. This preheater is used in conjunction with an air heater and eliminates " blushing " and " blooming " from sprayed cellulose; both units operate on alternating-current supply and are fitted with controlling thermostats.

WHEELED TRACTOR

Heavy Diesel-driven tractors and their associated equipment, together with Diesel-driven road rollers, predominated on the joint stand of Marshall, Sons and Company, Limited, Gainsborough, and John Fowler and Company (Leeds), Limited, Hunslet, Leeds. In addition to the " Road Marshalls " covering the 8 to 10 ton and the 13 to 15 ton sizes, two new models were on show: the Junior Tandem with a weight range of between 35 and 50 cwt. and a " Six-Eight " in the range of six to eight tons.

The Fowler series of " Challenger " crawler tractors, of from 50 to 150 brake horse-power, have already been described in ENGINEERING in great detail (page 627, vol. 177, May 14 last). The tractors were all displayed fitted with various auxiliary units. Thus, the 150-brake horse-power Challenger 4 was shown with a Blaw Knox cable angledozer and " K " type cable-control unit; the " 3 " with a Marshall side-boom crane, which has a maximum lift of approximately 18 tons at 4 ft. overhang; another " 3 " was shown with a Bray hydraulic angledozer and a Fowler logging winch; the smallest of the series, the 50-brake horse-power " No. 1," was also shown fitted with a Bray angledozer and a Blaw Knox " A "-type cable-control unit.

A new model on the stand was the Marshall M.P.6 tractor illustrated in Fig. 10, opposite. It has been designed specifically for the cultivation of large areas, but the pneumatic tyres should make it adaptable to a wider field of industry. The engine is a six-cylinder Leyland Diesel developing 70 brake horse-power at 1,700 r.p.m.; in top (No. 6) gear, the tractor has a maximum forward speed of 14·6 m.p.h., and the two reverse gears give it speeds of 2·78 and 4·46, these being attained on level tarmacadam with the tyres in water ballast. The power take-off is capable of transmitting the full available effort at 544 r.p.m. It is expected that models of this type will be available for general delivery in 1955.

ROCK CRUSHER

The principal exhibit on the stand of Armstrong Whitworth (Metal Industries), Limited, Gateshead-upon-Tyne 8, has been a No. 56 Kue Ken jaw crusher, claimed to be the most powerful and economical for its size that is available. It is illustrated in Fig. 11, opposite. With an all-up weight of 7,210 lb., its rated capacity is approximately 50 tons per hour at a 3-in. jaw setting. The feed opening is 24 in. by 12 in. wide and will accept 8-in. to 9-in. lumps.

Flood lubrication ensures cool running at 365 to 400 crushing strokes per minute; this means a higher capacity and an evenly crushed product. The elimination of a great deal of the wasteful rubbing normally associated with this type of machine has brought about a considerable extension in the life of the jaws. Protection from tramp iron is provided by a simple but effective overload device.

To demonstrate the long-wearing properties of the Kue Ken crusher jaws, two jaws were on display at the stand. Though there was little to choose between them, one was new and unused whereas the other had been in service for nearly two years crushing Scottish Whinstone.

TRAILER-MOUNTED PUMP

Auto-Diesels, Limited, Uxbridge, were showing examples from their range of generating, welding and pumping sets. One of the pumps was the " Floodmaster " D.W.6, a trailer-mounted version of which is shown in Fig. 12, opposite. This is a 6-in. heavy-duty centrifugal pump with a capacity of 75,000 imperial gallons per hour against a 10-ft. head. It is driven by a Lister F.R.4 Diesel engine, rated at 36 brake horse-power at 1,800 r.p.m. The engine is totally enclosed in a sheet-steel housing with removable side panels, and has an air cleaner and a silencer.

Both this and the 8-in. model have a maximum pumping head of 110 ft. and a maximum lift of 25 ft. They have automatic priming by water recirculation, and the three-bladed open type of impeller can handle water with up to 25 per cent. of solids in suspension. The wear plates on each side of the impeller can be adjusted to maintain maximum efficiency.

To be continued

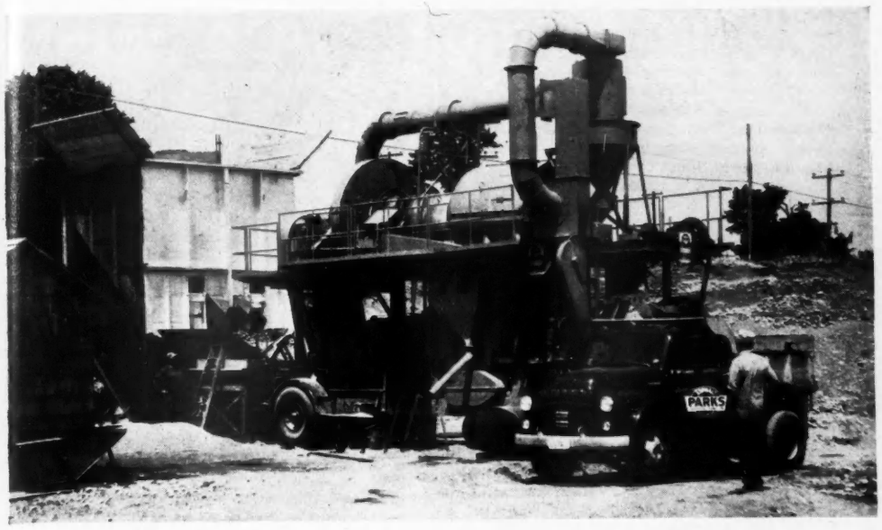


Fig. 7 Tar macadam has many advantages as a road surface and forms a very effective top dressing to soil-stabilised sub-grades. The Parker "Starmix" is a fully mobile asphalt-mixing plant with a medium capacity of between 12 and 25 tons per hour.

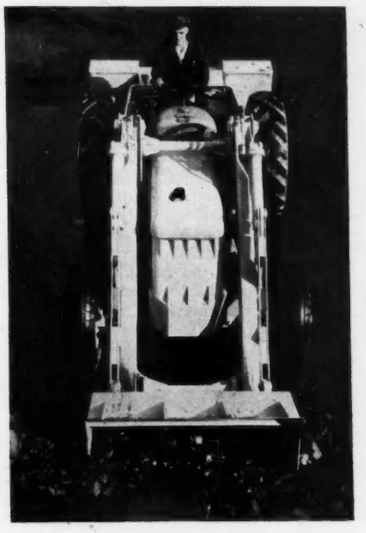


Fig. 8 On public view for the first time is the Muir-Hill 2-WL hydraulic loader fitted with a 1-cub. yd. bucket.

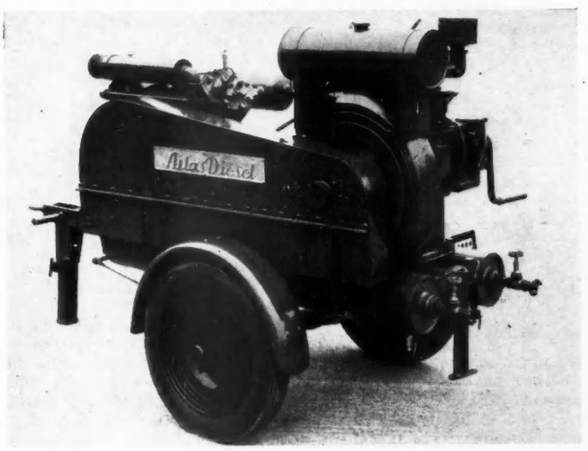


Fig. 9 The portable Atlas air compressor is driven by the new Armstrong Siddeley air-cooled Diesel engine. The engine has a maximum output of 11·6 h.p., the compressor a free-air capacity of 37 cub. ft. delivered at 80 lb. per square inch.

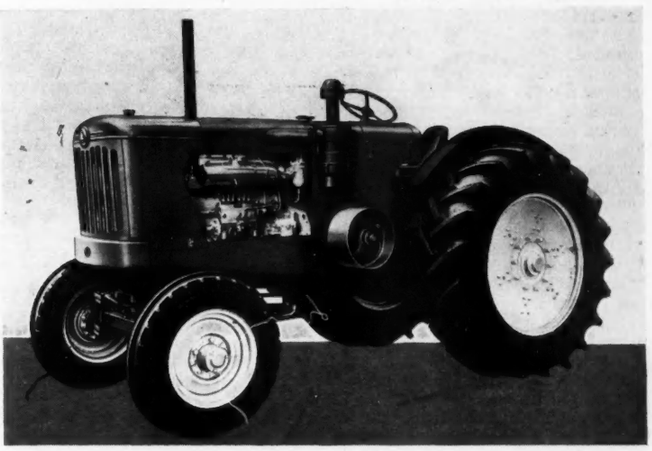


Fig. 10 Designed specifically for the cultivation of large areas the Marshall M.P.6 tractor is fitted with large pneumatic tyres. The Leyland Diesel engine develops 70 b.h.p. at 1,700 r.p.m. to give the tractor a maximum road speed of 14·6 m.p.h.

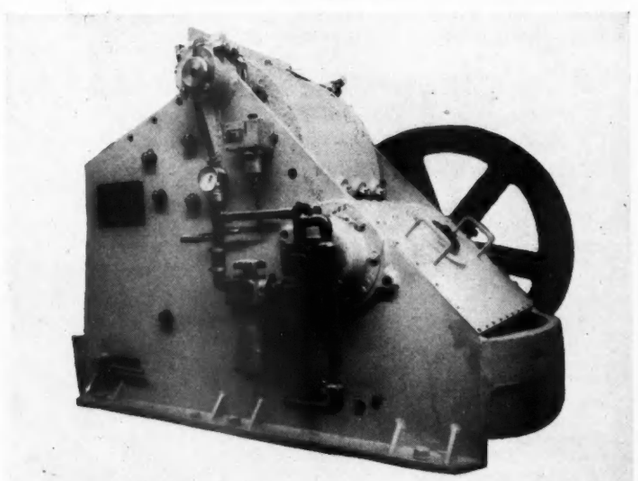


Fig. 11 The Armstrong Whitworth "Kue Ken" crusher has a rated capacity of approximately 50 tons per hour. Flood lubrication has been employed to permit a high working rate so as to obtain a uniform end product.

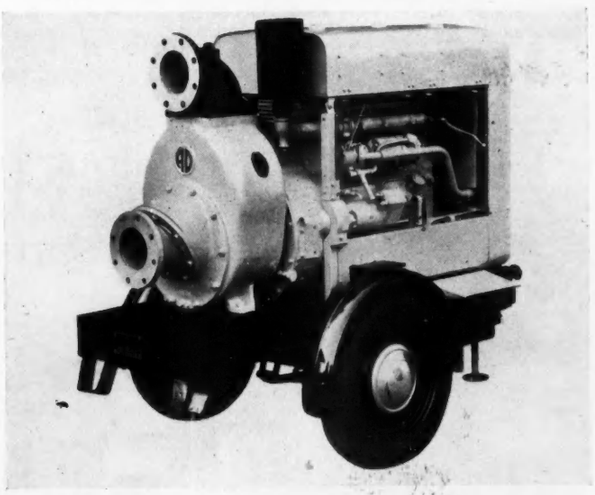


Fig. 12 Driven by a Lister Diesel engine rated at 36 h.p. at 1,800 r.p.m., the new Auto-Diesel 6-in. centrifugal pump has a capacity of 75,000 gallons per hour against a 10-ft. head. It is kept primed by recirculation.

ELECTRICITY SUPPLY IN JAMAICA

New Steam Station Commissioned

The commissioning of a new steam power station at Hunts Bay, Kingston, will do a great deal to relieve the difficulties of the Jamaica Public Service Company, which have been caused by plant shortage. Hitherto an electricity supply on the island has been given from four water power, six Diesel and one steam station. The Diesel stations, however, independently feed a small area in the north so that most of the main requirements are obtained from one steam and three water power stations. The steam station is equipped with three Brush-Ljungstrom turbo-alternators with a total installed capacity of 5,800 kW and which have been operating for many years, one as long ago as since 1925. There is also a 3,500-kW set of American manufacture, which was erected during the war.

Apart from plant shortage a further operating difficulty arises from the heavy rainfall. Normally there is a considerable pumping load for irrigation purposes, but this disappears temporarily during the rainy period. During this period, too, the water power stations must be fully loaded to avoid waste, as there is not much storage capacity. The net result is that the load on the steam station varies considerably.

The steam raising plant at the new station is installed out of doors, as shown in Fig. 1. It was manufactured by Babcock and Wilcox, Limited, Farringdon-street, London, E.C.4, and is of that firm's integral furnace type. It consists of a boiler with an output of 130,000 lb. of steam per hour at a pressure of 415 lb. per square inch and a temperature of 810 deg. F., the feed temperature being 300 deg. F. It is arranged for natural circulation and has a water-cooled combustion chamber and welded drum. There are 17 Cyclone steam separators in the upper drum. Firing is by oil, there being four steam atomising burners which are supplied from a pumping unit comprising a Weir steam pump and a Hamworthy electrically-driven pump with a capacity of 10,000 lb. per hour. Fully automatic control for varying the fuel and air flow is installed.

Associated with the boiler is a tubular cross-flow air heater with one gas pass and three air passes, the heating surface being 15,700 sq. ft. The draught plant consists of Davidson induced and forced fans of the single-inlet type with forward blading. All these fans are driven by Brush motors which, as they are installed out of doors, are totally enclosed.

The generating plant at Hunts Bay, which is illustrated in Fig. 2, consists of a Brush Ljungstrom set of the double-rotation type which has been designed to give a continuous maximum output of 12·5 MW at 13·7 kV. At present the set will be run at 2,400 r.p.m. to enable it to supply the existing 40-cycle system, but it will be possible by slightly modifying the turbine blading and alternator windings to convert it to 50-cycle operation at some future date.

The turbine is arranged so that steam can be extracted at two points for feed heating purposes. Second stage feed heating is carried out in a combined direct contact and storage heater, which embodies a de-aerator for dealing with the 2,500 gallons of condensate in the storage tank when starting up from cold. The final stage of feed heating is carried out in a high-pressure heater after the feed pump.

Steam is exhausted into a condenser with aluminium-bronze tubes to resist the corrosive effects of sea water and so arranged that cleaning can be effected while the set is running. To prevent marine growths developing the water, after passing through a rotary screen on its way to the pumps, can be re-circulated through the inlet and outlet flumes and brought up to a temperature of about 130 deg. F.

The control room is situated between the turbine room and the boiler end of the building, the surge and evaporated water tanks, the de-aerator and storage tank, being on its flat roof.

The station is designed for unit operation so as to reduce the staff. For that reason an elaborate system of alarms has been provided to indicate high and low condenser levels, high and low de-aerator storage-tank levels and low and high pressure heater levels. Automatic equipment for reducing the load should the vacuum fall is also installed; and the set is shut down altogether if the vacuum drops below about 12 in. of mercury.

The consulting engineers for the Hunts Bay station are Ewbank and Partners, 10 Grosvenor-place, London, S.W.1. Work is just starting on another section which will include a second outdoor boiler and duplicate turbo-alternator.

* * *

ELECTRONIC FAULT-FINDER

Sensitive Industrial Stethoscope

For checking the operation of running machinery a new type of industrial stethoscope has been developed recently by Bonochord, Limited, 48 Welbeck-street, London, W.1, and is being marketed by William Deneen and Associates, Netherton-grove, Chelsea, London, S.W.10. Known as the "Auditec" electronic fault-finder, it is claimed to be the first British industrial stethoscope employing electronic amplification, and its range of sensitivity is considerably greater than that of existing acoustic instruments.

The electronic fault finder, shown in the accompanying illustration, consists of a sturdy wooden

Industrial stethoscope with electronic amplification; sensitivity is said to be greater than that of conventional acoustic instruments.

casing housing a three-stage stabilised-circuit amplifier, freely suspended to reduce shock and vibration, and a combined high-tension and low-tension battery with a life of about 300 hours. The casing, which in use is slung over the shoulder, is provided with sockets for plugging in a pair of lightweight comfortable headphones and a detector probe. The latter has an insulating plastic handle enclosing and protecting the microphone from damage and moisture, and can be safely used even when in contact with high-tension voltage. The metal probe itself can be removed by unscrewing it and replacing by a longer special-purpose probe.

The instrument is provided with a volume control adjustable over a wide range, and a two-position frequency control. The low-frequency position, which covers the widest frequency range, is suitable for testing heavy slow-running machinery and low-pitched sounds. For high-speed movements, the control is moved to the high-frequency position which cuts out the low-frequency response.

By enabling incipient faults to be located rapidly without interrupting the running of the machinery, the electronic fault detector can eliminate losses in production time and can speed up maintenance work. Among its applications may be mentioned fault detection and quality control for all moving machinery, engines, transmissions and bearings of all types, pipelines, fans and heating systems. It can be used, for example, for checking watch movements or for large refrigeration plants.

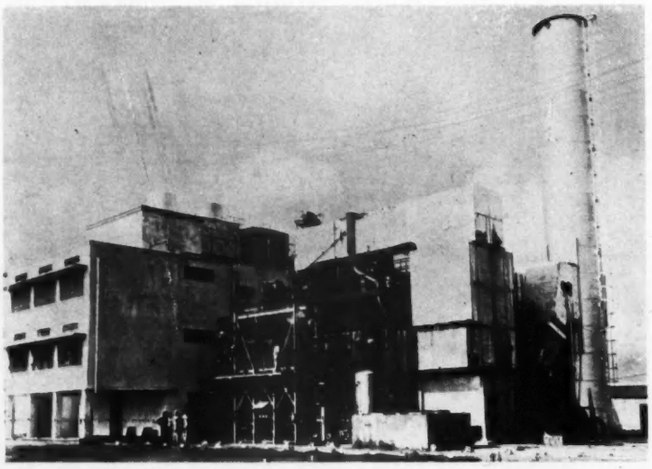


Fig. 1 12·5-MW power station with outside boiler plant.

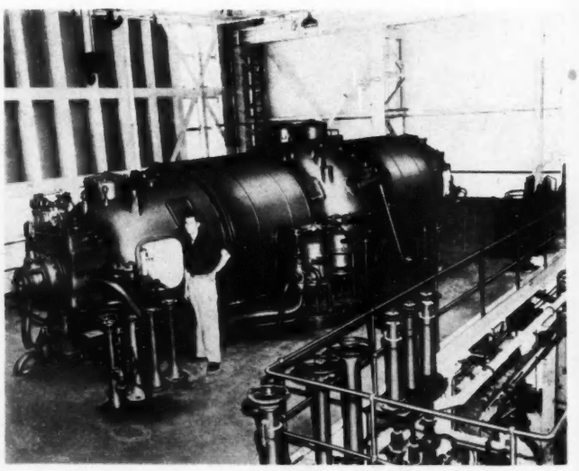


Fig. 2 Turbo-generating set supplying an existing 40-cycle system.

AUTOMATIC CONTROL OF BOILERS

FUEL AND AIR REGULATED BY GRID-CONTROLLED RECTIFIERS

The Huncoat power station, near Accrington, of the British Electricity Authority is at present equipped with three boilers with individual outputs of 305,000 lb. of steam per hour at a pressure of 625 lb. per square inch and a temperature of 860 deg. F. These boilers, which were manufactured by Simon-Carves, Limited, Cheadle Heath, Stockport, are fired by pulverised fuel, and their auxiliaries are driven by variable-speed direct-current motors, operating in conjunction with grid-controlled and constant-voltage mercury arc rectifiers. An automatic system, which has been jointly developed by Electroflo Meters Company, Limited, Park Royal, London, N.W.10, and the General Electric Company, Limited, Kingsway, London, W.C.2, has been installed for controlling these auxiliaries. This has been designed to ensure that a balance is maintained between the heat input to and the heat output from the boilers, and that the relationship between the air and fuel supply is correct at all loads and with different classes of fuel.

To ensure these conditions the steam pressure is used as an index of the balance between the steam demand and the steam supply. A change in the steam pressure causes the amount of fuel supplied to the boiler to be varied to the extent necessary to restore the pressure, and also adjusts the output of the forced draught fans. The fuel/air ratio is maintained constant by continuously measuring the steam and air flows, any departure from a predetermined figure being corrected by automatically altering the amount of fuel supplied to the boilers. The combustion chamber pressure is maintained at the desired value by controlling the induced draught fans.

DETAILS OF CONTROL SYSTEM

A diagram of the system adopted to fulfil these conditions is given herewith. It comprises a master steam pressure controller, which continuously measures the pressure in the main steam header and transmits compressed air to the control equipment. The pressure of this air is termed the master loading pressure, since its value is dependent on the load. It is indicated on the control panel of each boiler by the height of one column of a three-tube manometer, the other columns showing the air and fuel loads respectively. The operation of the controls is thus easily observable. The control panels also carry maximum and minimum loading units, so that the range of control for each boiler can be pre-set. Further, provision is made so that a change-over can be made to a manually-set master loading pressure, and the boiler thus operated at a constant evaporation instead of at constant pressure.

The master loading pressure is transmitted from the control panel through branches to both the fuel and air flow regulators so that their operation is co-ordinated. As regards fuel control, the direct-current motors driving the fuel feeders and the exhausters on the pulverisers are supplied from a constant voltage rectifier, their speed being variable by field rheostats. The master loading pressure acts on regulators which actuate power cylinders, and these cylinders in turn adjust the rheostats to comply with the new load conditions.

The master loading pressure is compared with the steam flow from the boiler at the steam flow/air relay and the pressure transmitted to the feeder and exhauster regulators is given a positive or negative correction when there is a departure from the desired ratio. A modulator in the master loading pressure line to the exhauster regulator ensures that the correct relationship exists between the load and the primary air flow. Should the mill tend to choke, the speed of its exhauster will be increased by its regulator, so as to maintain the primary air flow. If this fails to clear the obstruction the primary air flow will be reduced below its normal minimum value, thus operating an anti-choke relay. The result will be a reduction in the master loading pressure of the regulator until the speed of the feeder motor has decreased to its minimum value.

FAN CONTROL

As will be seen from the diagram, the master loading pressure also acts on the regulators which control the forced draught fans and thus adjusts the speed of the latter so as to produce an air flow which is proportional to the load. Hence both the fuel and air supplies are co-ordinated to give the maximum combustion efficiency and the correct heat output as required by the load.

As will be also seen from the diagram, the armatures of one induced draught and of one forced draught fan motor are connected to a grid-controlled rectifier, so that the two fans operate as a pair, while the fields of these motors are excited from the constant-voltage rectifier. The main speed control is effected by varying the armature voltage, this variation being initiated by regulators of the " positioning " type, which are operated by the master loading pressure. These regulators actuate phase-shifters which, in turn, alter the output of the grid-controlled rectifiers and consequently the armature voltage of the motors. In order that this adjustment may be precise the air flow is measured continuously by the forced draught regulators and balanced against the master loading pressure. Any error in the air flow is then corrected by automatically adjusting the trimming rheostats in the motor field circuits. This system is so arranged that the phase-shifter regulators are the first to operate, the field rheostat control being tuned to provide stable operation.

COMBUSTION REGULATOR

As each grid-controlled rectifier supplies one forced draught and one induced fan motor a change in the load on the boiler will alter the voltage applied to the armatures of the latter. Accurate control of combustion is provided by a separate regulator, which balances the actual combustion chamber draught against a pre-set value and operates the shunt field rheostats of the induced draught fan motors.

Manual, or more accurately semi-automatic, control of the air pressure is possible. This operates the control units and their associated power cylinders, while the individual regulators are actuated automatically so as to maintain constant the rating set by the control hand wheel. During manual control, therefore, the speeds of all the units are maintained at their correct relative values and incorrect adjustment of individual controls is avoided. On the other hand, when the control is fully automatic the pressure in the air lines, which is determined by the master steam pressure controller and by measuring the ratio of steam to air flow, automatically reflects the load on the boiler at any instant.

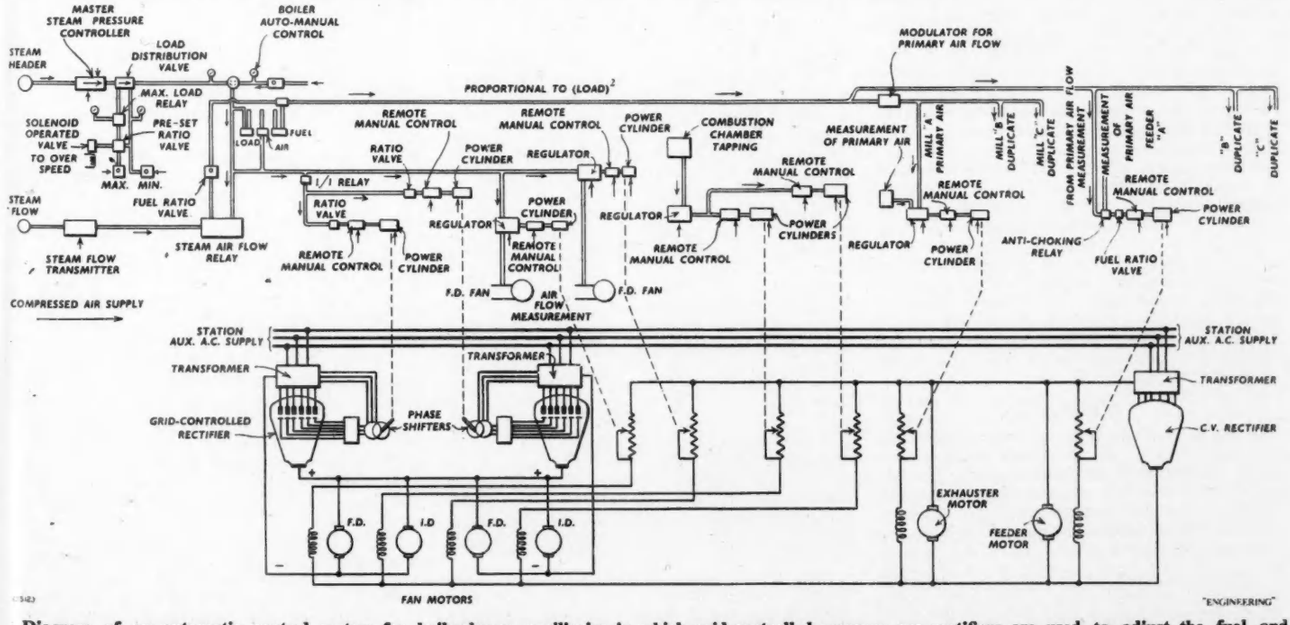


Diagram of an automatic control system for boiler-house auxiliaries in which grid-controlled mercury arc rectifiers are used to adjust the fuel and air supplies according to the load, quality of fuel, etc.

"SANDWICH" MATERIALS TO RESIST HIGH TEMPERATURES*

SKINS BRAZED TO METAL HONEYCOMB CORES

By John V. Long and George D. Cremer†

Since all-metal honeycomb sandwich materials offer a practical solution for making components to withstand elevated temperatures up to at least 1,500 deg. F., the Solar Aircraft Company, San Diego, launched a development programme to produce these structures by high-temperature metallurgical jointing techniques. The programme includes basic design studies, methods of core manufacture and contouring, brazing-material studies, production brazing techniques, physical testing, and service evaluation.

CORE DESIGN AND CONSTRUCTION

Steel and high-alloy sandwich core is usually manufactured in square, hexagonal or waveform cell types.

The "Squarecell" core is manufactured in the fully open condition, but it may be collapsed if grinding or machining operations are required. Such straight-cell cores are "anticlastic," i.e., when the core is bent in simple curvature it reacts by assuming a saddle condition, as in Fig. 1.

Another interesting core, notable for its optimum strength-weight design is the "egg crate." In this core the longitudinal and transverse ribbons are each slotted half way and then simply assembled slot to slot. This core resists bending completely along the longitudinal and transverse axes, while intermediate bending between these directions is acutely anticlastic.

The types of core just described are in general not suited for sandwich parts subjected to severe two- or three-dimensional curvature.

Two flexible-core designs which have been used are a finely corrugated core assembled in square-cell fashion which exhibits great flexibility, and a core stabilised by longitudinal ribbons. This latter design is known as "Multiwave." "Sinecell" core, illustrated in Fig. 2, permits two- and three-dimensional curvatures of a lesser degree.

Adhesive bonding and resistance welding are the two chief methods of assembling ribbons into core. Other techniques include wire stitching, eyeletting, and slotting. A process not employing ribbons but rather starting from a single sheet makes core in a manner similar to the manufacture of "expanded metal." Fig. 3 shows such a core which, being open at the nodes, holds promise for applications where fluid flow and heat transfer between skins and core is desired.

Machining or grinding flat honeycomb core is not a serious problem if the core can be collapsed for the operation. However, if the core cannot be collapsed or the surface is to be contoured, a real problem presents itself. One solution is to freeze the expanded core in ice and perform the necessary milling operations at subfreezing temperatures. Another employs a plaster-of-Paris composition to hold the core for contouring. Electrical disintegration is another technique for core contouring which may prove practicable in production.

BONDING

Resistance welding has definite possibilities for bonding the face skins to the honeycomb core. Severe problems are, however, encountered in producing consistently high-quality welds in reasonable continuity. Furthermore, there are difficulties in non-destructively inspecting such welded panels.

In the Solar company's experience only brazing assures a continuous, high-strength metallurgical joining of components. Due to the formation of fillets between mating surfaces, greater bond area results with attendant uniform stress distribution. Also, the skins spanning each cell are further stiffened or stabilised—a significant advantage when relatively thin faces are employed. Furthermore, the brazing alloy infiltrates the node laps with consequent sharp improvement in their column and shear properties. With excess braze material, sandwich strengths increase further; the weight economy, however, suffers at a progressively alarming rate.

FABRICATION

Clean, degreased, and occasionally pickled metal surfaces are specified. The brazing alloy is applied as a granular powder in measured quantity directly to the core nodes and is held in place by a volatile plastic solution. Small amounts of special fluxes may be applied during this operation.

Preliminary experiments have been made which show the feasibility of applying the braze-flux mixture in a plastic film or tape. This film is simply placed between the core and face-sheet.

The actual sandwich fabrication involves (1) correct pre-positioning of brazing alloy and flux, (2) correct location of the structure components and fixtures, (3) accurate maintenance of the assembly during the brazing-joining operation, with metal-to-metal contact between the faces and core, (4) controlled heating and cooling rate to prevent warpage and stressing of the part, (5) maintenance of adequate atmospheric protection to ensure a clean, non-oxidised assembly and high-quality braze metal joints, (6) controlled post-heat treatment to develop the desired metallurgical conditions within the sandwich materials, and (7) sizing, coining, or other plastic deformation of the brazed panel to develop a precise part and/or to effect strengthening by cold work.

Fig. 4 is the desired metal-to-metal T-butt-joint which has continuous fillets and exhibits optimum strength with excellent weight economy.

The most significant single factor in assuring a high standard of brazing is maintenance of intimate contact of the components throughout the brazing operation. This must be done concurrently with achieving the desired structure-form, which may specify aerodynamic smoothness on both surfaces—a most difficult combination, especially since the brazing temperatures are in the neighbourhood of 1,900 deg. F. Frequently curved panels are easier to fabricate than flat panels.

While non-destructive testing standards have not been established for all-metal honeycomb structures, there is good reason to believe that both X-ray and sonic methods hold promise for determining the existence of braze fillets and metallurgical bonding.

PHYSICAL PROPERTIES

Remarkable stiffness is added to thin faces by stabilising them with honeycomb core. The compressive strength of the sandwich is greatly dependent upon cell design. Through proper choice of cell configuration and material, values as high as 4,000 lb. per square inch have been realised in 2-mil, ¼-in. cell core.

The creep properties of high-temperature brazed construction are claimed to be superior to adhesive-bonded at all temperatures. Tests up to 1,650 deg. F. have shown the brazing materials to have excellent creep resistance.

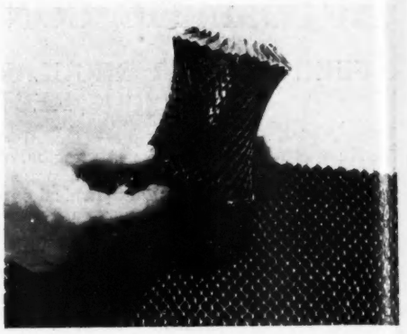


Fig. 1 When bent, "Squarecell" core becomes concave in a direction perpendicular to the line of bending, assuming the saddle form shown here.

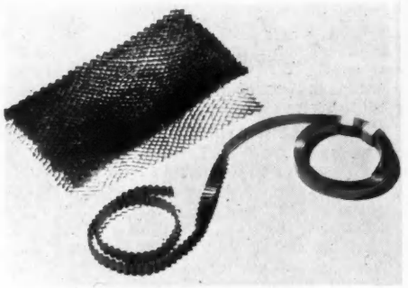


Fig. 2 "Sinecell" core permits a certain degree of two- and three-dimensional curvature.

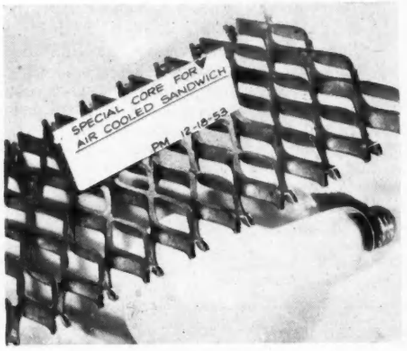


Fig. 3 Core manufactured from sheet metal. Open at the nodes, it has applications where fluid flow or heat transfer is required between skin and core.

The favourable impact strength of an all-metal sandwich is indicated by battle damage experiments. Fig. 5 shows a typical shroud-type honeycomb panel that has been subjected to a 20-mm. projectile. It will be noted that the extent of the damage is localised and skin peeling halted at the cell wall joint.

While design data for metal honeycomb structures is at present meagre, active investigations are being sponsored by the Wright Air Development Centre at the Forest Products Laboratory, United States Department of Agriculture. The Solar Aircraft Company are also conducting a physical testing programme.

Strength values are dependent upon a given sandwich design. As a specific case consider a heat-treated panel ½ in. thick, constructed of 17-7PH steel with 0·002 in.-¼ in. square-cell core and 0·015-in. thick faces. The results which have been obtained are shown in the Table on the opposite page.

* Lecture entitled "High-Temperature Sandwich Structures," presented at the Society of Automotive Engineers, Los Angeles Aeronautic Meeting, October 5-9. Abridged.

† Solar Aircraft Company, San Diego, California.

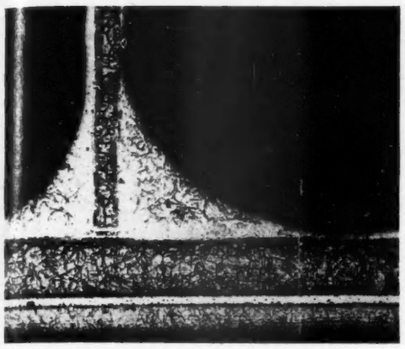


Fig. 4 High-quality skin-core joint, showing the deep fillets of brazing material.

Temperature, deg. F.	75	800	1,000
Tensile strength, lb. per sq. in (face after brazing) ..	175,000	115,000	60,000
Edge compression, lb. per sq. in.	180,000	130,000	80,000
Flat compression, lb. per sq. in.	4,000	2,600	1,300
Maximum core shear, lb. per sq. in.	500	400	350

AFTERBURNER SHROUD

An interesting application for brazed high-temperature honeycomb sandwich was a stand-off self-supporting afterburner shroud around a tailpipe that ran above 2,000 deg. F. Both insulation and reflective heat-barrier properties were desired in a strong lightweight fatigue-resistant structure. From experience with solid sheet-metal shrouds, sandwich service temperatures were predicted to range from 750 deg. to 900 deg. F.

The completed unit shown in Fig. 6 is believed to represent the largest commercial all-metal honeycomb sandwich structure known. It has proved successful in flight tests under severe conditions. Eight curved panels were assembled by edge fastenings to form split halves of a tube 5 ft. long by 2 ft. in diameter.

The thin-skinned honeycomb sandwich accounted for only one-half the 28 lb. total weight. Some 14 lb. of massive sheet metal were required for edge strips, channels, pads, rivets, and attachment flanges, which indicates the opportunity for weight reduction by design refinements.

POROUS SKIN SANDWICH

Highly refined fabricating techniques have made it practical to produce high-strength sandwich having one or both faces of a perforated or permeable metal. Such constructions are designed for applications requiring fluid flow through a skin for cooling or heating purposes. This composite material has the strength-weight advantage of all-metal sandwich in addition to serving as a fluid manifold. Moreover, as the honeycomb core is an exceptional stabiliser, very thin skins become feasible, thus reducing the pressure drop and the panel weight. Possible aircraft applications for porous faced sandwich include control of sweat cooling, anti-icing, aerodynamic bleed, and of the boundary-layer.

The aircraft industry has made considerable use of marcel or corrugated sandwich core for heat exchangers, in anti-icing leading edges, air-cooled turbine blades, and heated inlet guide vanes. Honeycomb offers the distinct advantage of substantially greater skin stabilisation, while accommodating the necessary fluid flow.

ROTARY PRESSURE SEALS

The Solar Company is currently exploring the possibility of using all-metal honeycomb construction as rotary pressure seals. The stationary seal member consists of ⅛-in. pitch Sinecell honeycomb core ½ in. thick, continuously bonded

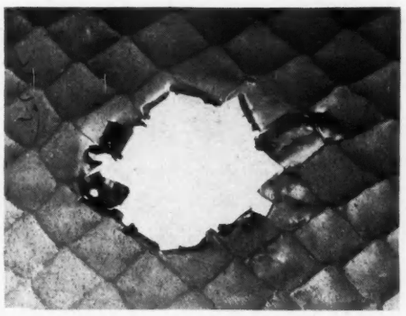


Fig. 5 This honeycomb panel suffered only local damage when punctured by a 20-mm. projectile.

by means of high-temperature brazing to a massive rim plate. Excess braze alloy is used to ensure heavy filleting at the base. A precision knife-edged disc or disc labyrinth would comprise the rotating seal member. Relative expansion and other mismatching between the disc and open-faced sandwich core can be accommodated by the rotating member cutting into the stationary core, thus making a self-matching unit. To prevent galling, special ceramic antigall coatings on the disc and/or core have been recommended. This appears to be promising for seal temperatures in the range of 1,000 deg. to 1,700 deg. F.

SHAPED SANDWICH

Experimental-shaped parts have been successfully machined by high-temperature brazing, using the plaster-support method. The jigging of the components is critical because intimate core-to-skin contact must be maintained during the brazing cycle. Due to the exceptional metallurgical bond strengths which characterise high-temperature brazed parts, it has been found feasible to stretch-form brazed sandwich.

A composite all-metal sandwich has been evolved for potential use as a rocket blast shield. This panel has a normal structural sandwich base upon which a refractory-filled honeycomb core and face sheet is superimposed.

Fig. 6 An afterburner shroud believed to be the largest commercial all-metal honeycomb structure so far made. It comprises eight curved panels assembled by edge fastenings.

In a direct rocket-blast test, the ⅛-in. refractory filling of bonded aluminium oxide showed marginal success in absorbing the blast pressure and heat. By virtue of honeycomb core reinforcement, this refractory withstood the blast without cracking or spalling in unmelted areas.

Further development of composite sandwich blast panels is planned to ensure complete protection of the structural base sandwich. Improved thermal shock and erosion resistance is expected by using a special graphite filling in place of the refractory alumina.

* * *

CENTAURUS AERO-ENGINE LIFE

1,250 *Hours Between Overhauls*

In less than 2½ years after entering airline service with British European Airways, the Bristol Centaurus "661" engines installed in B.E.A.'s Elizabethan aircraft have been approved for a life of 1,250 hours between overhauls. On March 23 the Air Registration Board granted approval for an overhaul life of 1,000 hours. Examination of Centaurus engines which had completed this period of service showed them to be in such excellent condition that, two months later, on May 31, the overhaul period was extended to 1,250 hours.

The Centaurus 661 engine, designed and constructed by the Bristol Aeroplane Company, Limited, Filton, Bristol, is an 18-cylinder two-row radial sleeve-valve engine with a two-speed supercharger and R.A.E.-Hobson injection carburettor, developing a maximum take-off power of 2,625 brake horse-power at 2,800 r.p.m. It is a descendant of the military Centaurus engine, the prototype of which ran for the first time in 1938, developing 2,100 brake horse-power. At the end of the War the engine was redesigned for civil applications.

Many of the moving parts were strengthened and copper cylinder heads, with steel skirts, were adopted in place of aluminium. This, in conjunction with the use of individual cooling ducts to each cylinder, gave more effective and well-distributed cooling. Other changes included the adoption of flexible mountings, an exhaust manifold, and a more accessible ignition system.

The Centaurus 661 ran for the first time in May, 1949, and entered commercial service in March, 1952, in the Ambassadors of B.E.A.'s Elizabethan fleet. Since then they have achieved an excellent record of reliability. In a total of 128,147 flying hours there have only been five failures requiring a propeller to be feathered during flight and only ten engine failures detected on ground inspection. The average achieved overhaul life exceeds 90 per cent. of the authorised figure—and this includes cases where engines have been removed prematurely not on account of failure but for reasons of expedience—e.g., to coincide with the aircraft check periods or to ensure maximum availability for the summer "peak" traffic.

It is of interest to note that, in contrast to British Overseas Airways Corporation, who run their own engine overhaul organisation, British European Airways contract their engine overhauls out—in the case of the Centaurus engines, to the Bristol Aeroplane Company, who operate an overhaul factory at Whitchurch, Bristol, for servicing Hercules and Centaurus engines. The Bristol company have contracted to supply engines for the Elizabethan fleet, plus a few spare engines held in a pool at London Airport, and to replace time-expired or failed Centaurus engines removed from the aircraft within a few hours. Thus B.E.A. only hold the engines actually in the aircraft and the central pool; engines passing through the overhaul shops are the property of the Bristol Aeroplane Company. Payment is on a sliding scale per aircraft hour flown—the longer the engines are flown, the lower the cost per hour to the Corporation.

DEVELOPMENT OF NEW ALLOYS FOR PERMANENT MAGNETS

The main objects of the Permanent Magnet Association are to conduct co-operative researches leading to the development of new alloys of improved magnetic properties and to investigate existing materials with a view to improving their qualities. The members of the Association are producers of high-grade steels and alloys, whose works for the most part are based in Sheffield and, for a number of years, research activities were carried out in their own works laboratories. Centralised research commenced in 1941 and equipment was originally housed in the Physics Department of the University of Sheffield. The expansion of the work, however, demanded extended facilities and a central research laboratory was built on a site at 84 Brown-street, Sheffield 1. This was completed in 1946 and gave facilities for the pilot manufacture and treatment of magnet castings, together with chemical, metallographic and physical laboratories and a workshop for the manufacture of instruments and apparatus.

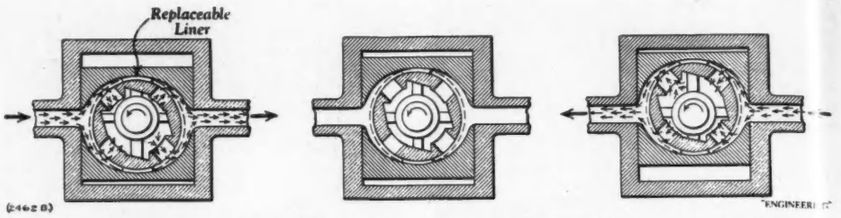
The addition of a second storey to the building, recently completed, has allowed the re-arrangement of the original laboratories in which equipment had become overcrowded. Furthermore, a library and conference room has been provided, and a variety of furnaces, recorders and controllers, which were previously scattered, now form a complete heat-treatment laboratory. There is also greater storage space and room for some future expansion.

The work of the laboratory has led to the establishment of accurate methods of magnetic testing and for the chemical analysis of the complex alloys used. Moreover, industrial magnet applications have been investigated to determine the most efficient magnet designs, and much fundamental research on the physical properties of magnet materials has led to a better understanding of the causes of high coercivity.

The Association inform us that they were the first to produce the now universally-known magnet material Alnico, which, as its name suggests, is an alloy of aluminium, nickel and cobalt, together with iron and other elements. They also developed the original anisotropic materials, which exhibit enhanced magnetic properties along one axis. This work led to the introduction of Alcomax and other uni-directional magnets. A more recent achievement was the production of the niobium-bearing alloys, Alcomax III and IV, which the Association describe as two of the most efficient permanent-magnet materials commercially available at the present time.

The latest advance in magnet alloys is Columax. This material is cast in such a manner that columnar crystals are developed with the same orientation as the preferred axis of magnetisation. This process involves an intricate technique in the foundry and is applicable only to simple shapes within certain limits of size. At present, this material has only a limited field of application, but, within that field, it exhibits considerably enhanced magnetic properties, as compared with Alcomax III. The Association states that Columax magnets of suitable proportions and design may be expected to have an average energy value of $(BH)_{max.}$ equal to 6·25 M.g.o. (mega-gauss-oersteds). Considerably higher values have been obtained from samples from which all the crystals in an unwanted direction have been removed. Thus, a report of tests carried out at the National Physical Laboratory on a sample of the alloy show this to have a $(BH)_{max.}$ value of 8·6 M.g.o.

It may be of interest to note, for the purpose of comparison, that the $(BH)_{max.}$ value of Alcomax II, introduced in 1945, is 4·5 M.g.o. that of Alcomax III, introduced in 1948, 5·0 M.g.o., and that of Alcomax IV, introduced in 1949, 4·5 M.g.o., with a coercivity value (H_c) of 750 oersteds.



These diagrams show how the eccentricity of the vanes is varied to regulate the amount and direction of flow of the liquid being pumped.

POSITIVE DISPLACEMENT ROTARY PUMP

BUNKERING UNIT WITH CAPACITY OF 1,500 GALLONS PER MINUTE

The largest pump yet made by Plenty and Son, Limited, Newbury, Berkshire, has been completed for the Anglo-Iranian Oil Company for use at Aden. An illustration of the pump undergoing trials is given below.

The pump is of the type introduced by Plenty and Son some years ago and which was described in ENGINEERING, vol. 140, page 498 (1935). The action is essentially that of the eccentric-vane type, but displacement is positive and the output can be varied independently of the speed. The latter characteristic offers many advantages in reducing the complexity of the drive and the control gear, enabling a constant speed motor to be used without having to interpose variable-speed or reverse gear.

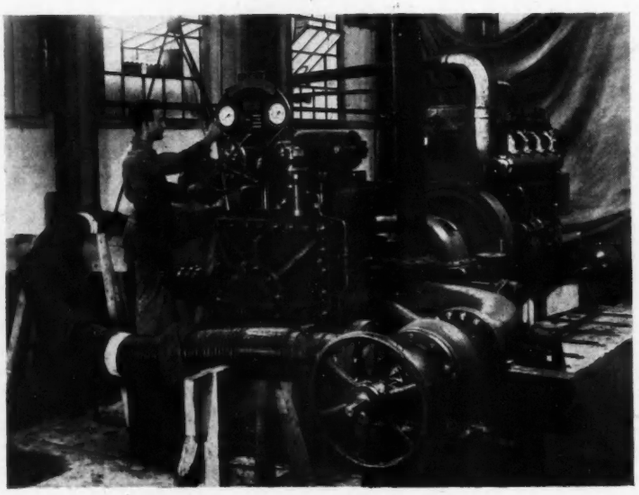
The action of these pumps is indicated by the three diagrams above. The two blades pass at right angles to each other through the spindle. They are free to slide across the spindle so that a greater or less amount projects, the bevelled ends of the blades resting against the inner faces of a cylinder known as the rotor which revolves with the blades and spindle. In the rotor are four ports through which the liquid being pumped passes in and out. The bevelled edges of the blades lying against the inner face of the rotor form wide sealing surfaces enabling the pump to operate against high pressures without excessive leakage or wear. Surrounding the rotor is a fixed liner, shown dotted in the diagrams, ports in which lead to the inlet and outlet pipes; this liner can be easily renewed.

In the "Universal" models to which the new pump belongs, the pumping rate can be varied by altering the degree of eccentricity. This is done by sliding the inner body (to which the liner is fixed) in relation to the spindle axis. In the first of the diagrams, this body is shown at one extreme of its travel causing the pump to give its maximum output from left to right; in the second the body is central, the eccentricity being therefore zero, and the pump is not passing any fluid although the spindle is still rotating; and in the third the body has moved to the other extreme and the pump is again delivering its maximum output, but this time in the opposite direction, namely from right to left. Any intermediate position can be chosen to give the output (or return) desired.

The pump that has been built for the bunkering installation at Aden has a capacity of 1,500 gallons per minute when running at 135 r.p.m. It is driven by a Crossley Q.V.D.4 Diesel engine which has an output of 200 b.h.p. at 500 r.p.m. This four-cylinder engine has a bore and stroke of 10·25 in. and 12 in. respectively. It is totally enclosed, with sliding covers to give access, and has an automatic lubrication system with a hand priming pump for use when starting (by compressed air at 250 lb. per square inch).

Speed reduction is by a Crofts gearbox, fitted with a clutch. The full output of the pump can be obtained with oils having viscosities ranging from 50 to 11,000 seconds Redwood No. 1 against delivery pressures up to 125 lb. per square inch. This performance requires the maximum output of the engine, but the pump itself is capable of giving full delivery of oils of 20,000 seconds at 300 lb. per square inch, the horse-power then required being about 500. Under reduced output, it has been run with light oils up to 400 lb. per square inch and can, of course, handle the heavier oils up to the maximum output of the engine. It can develop a vacuum of 26·5 in. of mercury.

In the illustration, the operator is adjusting the pumping rate by the gear which alters the



Under test, the variable delivery pump delivered 1,500 g.p.m. of oils ranging from 50 to 11,000 seconds Redwood No. 1 against a pressure of 125 lb. per square inch.

eccentricity. On the top of the pump behind this gear is a full-bore relief valve which can be reversed to suit the direction of flow. The handwheel in the foreground is for adjusting the pumping pressure while on test.

The reversing action of this pump offers a useful safety factor in operation, for should an emergency arise at the delivery end, a relay can be made to operate the reverse automatically, and the fluid will be pumped away from the danger zone and back to the bunkers. It also has the advantage that pipe lines can be emptied of one sort of oil, before another grade is pumped through. This is particularly applicable in bunkering installations, where it enables one pump to handle all supplies without undue losses. A pair of pumps driven by one engine or motor can be used for blending, as the quantity pumped by each can be regulated exactly to give the required proportions, a master controller being used to regulate the total flow. The model being supplied to Aden has a standard rating of 350 tons per hour; plans for one of 750 tons per hour have been prepared.

TESTING AND RUNNING-IN TRACTOR AND CAR ENGINES

NEW DAVID BROWN PLANT NOW IN USE

A new engine test-house which is believed to be among the most advanced in the country, both in layout and equipment, has recently been brought into service by David Brown Tractors (Engineering), Limited, at their Farsley Works, near Leeds. Experimental work carried out during recent years at the company's main headquarters at Meltham, near Huddersfield, has largely influenced the design and methods chosen for the new test plant. It will be used for running-in and power-testing the engines which are assembled at Farsley for fitting in David Brown agricultural and industrial tractors, and in Lagonda and Aston-Martin cars.

RUNNING-IN ON COAL GAS

Five fuels are available for the test beds. Coal gas is selected for running-in purposes but alternative fuels are available if required. Each engine is power-tested on the fuel for which it is specifically designed. On account of the wide variety of tractor engines manufactured to meet the demands of farmers at home and overseas, it has been necessary to provide supplies of gas oil, vaporising oil, petrol and lamp oil, all fed from storage tanks alongside the main building.

The decision to run-in engines on coal gas was made on the grounds of both economy and efficiency, for gas is not only a cheap fuel but has the added advantage of leaving little solid deposit in combustion. The engine is started by an electric motor, with a clutch that disengages automatically at 750 r.p.m.

The original testing and running-in plant comprised twelve tractor-engine beds and two car-engine beds, all fulfilling dual roles. The new test plant has seventeen dynamometer test beds and nine running-in beds for tractor engines, three test and three running-in beds for car engines, with provision for further development to almost double the capacity when required. The bases for the additional beds have been laid as part of the general scheme.

The new building is 250 ft. long by 37 ft. 6 in. wide and is adjacent to the main works. Fuel and water supplies have been laid in covered trenches, thus avoiding interference from supply piping and leaving the maximum area clear of obstruction. Centrally placed on one side of the test-house is an enclosed section devoted solely to storage, inspection and testing of Diesel injector equipment.

Since water is used as the hydraulic medium in the dynamometers, as well as for cooling purposes, the plant has been equipped with a pumping house and cooling system to effect re-circulation. The main tank, of 20,000 gallons capacity, is divided into hot and cold sections. Water from the cold section is supplied to the dynamometers and to header tanks on each test bed by a pump capable of delivering 15,250 gallons per hour. Hot water, when discharged, flows into a common trench, to be returned by gravity flow to the hot well in the reservoir. A second pump, also of 15,250 gallons per hour capacity, passes the hot water to a cooler, from which it discharges into the cold tank at a temperature of not more than 100 deg. F. in summer conditions. Another pump circulates water through an oil system on the car-engine beds. Each of the pumps is duplicated, one to operate on load and the other on reserve, so that a breakdown in the circuit cannot bring the whole plant to a standstill.

FUEL AND OIL STORAGE

The bulk storage tanks for fuels and lubricating oil are situated at one corner of the site, the fuels flowing by gravity to the engines and the lubricating oil being fed under pressure to the running-in beds.

Petrol is stored in an underground tank of 1,000 gallons capacity, from which it is pumped to a 50-gallon header tank and thence to the test beds. Overhead tanks are used for storing gas oil and vaporising oil, with capacities of 2,000 and 1,000 gallons, respectively. As comparatively few lamp-oil engines are built, only 500 gallons of this fuel are stored, feeding to two of the beds.

Unused oil and purified lubricating oil are stored in separate tanks, each of 1,000 gallons capacity. When an engine is drained on the test bed the used oil is piped to underground tanks. After its condition has been tested, the oil is either disposed of as waste or passed through a motor-driven centrifugal purifier and returned to the overhead tanks for re-use. When filling an engine with oil, an operator can measure the quantity accurately by a gauge incorporated in the pressure flow system.

Noise outside the building has been kept to a minimum by piping each exhaust to an absorption-type silencer mounted on the outside wall. Single-chamber silencers are fitted on the exhausts from the tractor beds, but the silencers on the faster-running car engines have primary and secondary chambers.

Hydraulic dynamometers are fitted throughout. The tachometers on the tractor beds record up to 5,000 r.p.m., though test speeds are normally only a little over 2,000 r.p.m.

The high-speed car engines run in three sound-insulated cubicles in a separate section of the building, and are coupled to dynamometers placed outside the cubicles, as shown in the right-hand illustration. On account of the high engine speeds these dynamometers have stainless-steel elements, and the latest type of electric tachometers reading up to 8,000 r.p.m. (normal test speeds up to 6,000 r.p.m.). The concrete bases of the car test beds are set in cork surrounds to reduce vibration to a minimum.

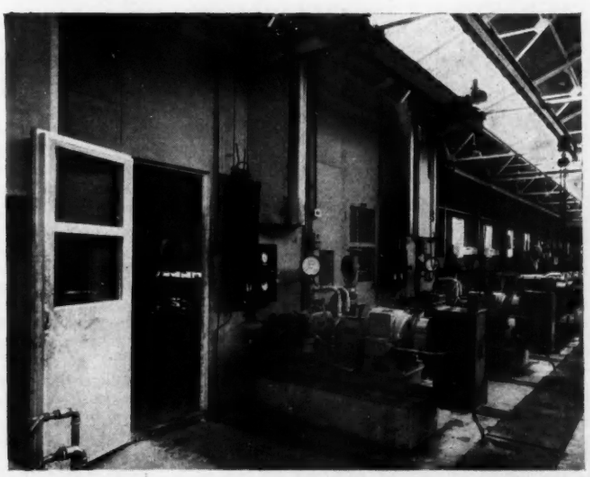
The whole of the plant was designed by the Works Engineer's Department of David Brown Tractors (Engineering), Limited, and the staff of that department supervised the construction.

★ ★ ★

GERMANIUM DIODES IN GLASS ENVELOPES

A technique has been developed by Mullard, Limited, Century House, Shaftesbury-avenue, London, W.C.2, whereby germanium diodes can be enclosed in glass envelopes with direct glass-to-metal fusion seals for the leads. Previously such fusion seals were not greatly used owing to possible damage of the germanium by the heating involved.

The new test-house has 17 dynamometer test beds and 9 running-in beds for tractor engines. Coal gas is used as the running-in fuel.



Lagonda and Aston-Martin car engines are run in three sound-insulated cubicles and are coupled to dynamometers outside the cubicles.

AUTOMATIC CHAIN LUBRICATOR

For Use with Conveyors

A new automatic chain lubricator is being produced by Clarke, Chapman and Company, Limited, Victoria Works, Gateshead-on-Tyne, for use with all types of chain conveyors. It can be engaged or disengaged, assembled or dismantled as a complete unit while the conveyor is running and is illustrated below.

The lubricator is arranged to work in conjunction with the chain sprocket wheels and is independent of chain speed. The mechanism of the lubricator is totally enclosed inside an oil-tight aluminium case, which forms an oil bath providing splash lubrication for the mechanism. The lubricator is simple and safe to operate and can be used by unskilled labour.

Various sizes are available depending upon the number of teeth in the sprocket wheel and the pitch of the chain. With two lubricators fitted at the tail end of a conveyor the increase in overall width of the conveyor is normally never more than 18 inches. When necessary the lubricators can be fitted at the driving-head end of the conveyor.

The lubricators are mounted on a stationary stub-type axle. The conveyor sprocket wheels, mounted on bearings, are free to rotate upon the axle. Although the centre portion of the lubricator can slide along the axle, it cannot rotate since it is locked radially by a square formed at the axle end. The casing of the lubricator is free to rotate round the stationary centre.

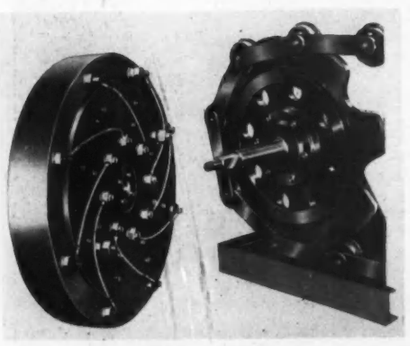
Equally spaced inside the casing are the injector rams, and mounted directly above each ram is a rocker arm and plunger—these vary in number according to the size of the lubricator. The pitch and pitch-circle diameter of the plungers correspond to the chain pitch and the sprocket-wheel pitch-circle diameter. Each plunger is spring loaded, and fitted to the end of the plunger is a special bell-mouthed self-centring nipple connector. At the outboard end of the lubricator casing is a collector manifold, for collecting and distributing lubricant to each of the injector rams, which are fitted with a non-return valve. A short length of high-pressure flexible piping runs between each ram and its nipple connector and a relief valve is incorporated at the nipple-connector end of each pipe. This valve is set at a higher pressure than the supply-pump feed, so that as the lubricant is pumped to the lubricator it forces out and fills each of the injector rams.

The lubricator unit is engaged by means of a hand lever which slides the whole unit along the axle. Two pins which are fixed to the lubricator casing then engage a steel driving ring formed as part of the chain sprocket wheel.

As the lubricator casing rotates each rocker arm is raised in turn and pushes forward its plunger. The self-centring end of the plunger engages at the correct moment with a chain nipple. The lubricant is then forced by the injector rams at high pressure through the nipple into the chain-link pin. As the lubricator continues to rotate, each rocker arm and plunger is withdrawn and each injector ram is recharged with lubricant. The length of time the lubricator unit is left engaged depends upon the length of the conveyor and the chain speed.

If the conveyor chain stretches or wears, thus increasing the chain pitch, the self-centring nipple connectors automatically adjust themselves, accommodating up to $+\frac{1}{4}$ in. on the pitch of the chain. Provision is also made for adjusting the lubricator if wear takes place on the chain sprockets. Being spring loaded, the plungers adjust themselves to any difference in the heights of the chain nipples.

The unit is designed for working under very bad conditions, such as dust and steam laden atmospheres. When these conditions are extremely bad a simple air-jet cleaning equipment is provided which automatically cleans each nipple before and after lubrication.



The automatic chain lubricator shown on the left is fitted to the stub axle of the chain sprocket. A driving ring on the sprocket engages with two pins on the lubricator casing and causes plungers in the lubricator to feed lubricant in turn to injection rams which force it at high pressure into the chain-link pin.

* * *

TIME-INTERVAL RECORDER

Planning Machine and Vehicle Maintenance

To register the true operating hours of vehicles, machine tools and process plant, and machinery of practically all types, with the object of facilitating the planning of preventive maintenance and operating schedules, an electrically controlled elapsed-time indicator of the chronometer type has been introduced by Cass and Phillip, Limited, Caslip Works, Mark-road, Adeyfield, Hemel Hempstead, Hertfordshire.

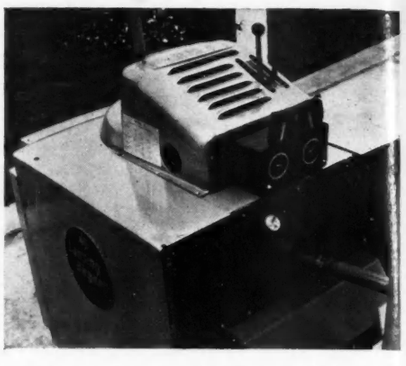
The new instrument, shown in the accompanying illustration fitted to a fork-lift truck, incorporates an electrically controlled clock mechanism, which is electrically linked with the machinery to be time recorded, either by connection to the starting battery—as in the case of a lorry, truck, car, tractor or public service vehicle—or by connection to the lighting circuit or to any other available low-voltage supply, or if required, by oil-pressure, air-pressure and vacuum feed.

The elapsed-time indicator is designed and installed so that it begins to record operating hours and minutes when the machine starts up or otherwise goes on load, according to the requirements of the user. Similarly, the instrument stops recording when the machine stops, or when the activity being metered ceases. Two important advantages possessed by the new elapsed-time indicator are flexibility of installation and flexibility of application.

In the model illustrated, two dials are internally connected through a gear train; one registers minutes up to a maximum of one hour, the other records the number of revolutions made by the minute pointer, thus registering hours, and enabling a total of 9,999 hours to be recorded before the instrument automatically resets itself to zero.

In installing the instrument it is only necessary to ensure that the elapsed-time indicator is provided with a suitable supply of electricity (the power consumption is negligible) and that the instrument control switch is automatically closed when the machine starts up, or when a specific phase of its activity commences. Similarly, the instrument control switch is arranged to open the indicator circuit when the activity in question ceases or when the machine shuts down according to the nature of the process.

In the case of a road vehicle, for example, the indicator could be switched on and off by the movement of a hand brake, and the control circuit could be switched on and off with the ignition. This would ensure that vehicle running hours were recorded, not gross engine running time.



The chronometer-type elapsed-time indicator is shown here mounted on a fork-lift truck. It automatically records the cumulative running hours up to a maximum of 9,999 hours.

The instrument is built to the highest precision standards, protection from rough usage being ensured by the fitment of Incabloc shock-proof jewelled bearings to the balance staff.

Operation is as follows: a balance wheel is made to oscillate by an armature, which swings in the gap of an electro-magnet. The electro-magnet is energised intermittently by a contact which makes and breaks the low-voltage supply circuit to the instrument. The self-starting control circuit is arranged so that when the supply is switched on, the make-and-break is mechanically connected, by means of a solenoid, thus energising the electro-magnet which in turn starts the balance wheel oscillating. At the end of an operating period the circuit is disconnected, allowing the balance wheel to come to rest.

A fluid sensitive diaphragm which actuates the auxiliary and main switches when deflected by fluid pressure can also be incorporated.

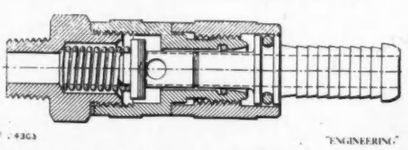
* * *

HEAVY-DUTY AIR-LINE COUPLING

For Pressures up to 300 *Lb. Per Sq. In.*

A new connector for coupling air-line hoses to main air-supply pipelines, particularly suitable for use in collieries and other heavy duties, has been introduced recently by Pneumatic Components, Limited, Eyre-street, Sheffield. It is available to fit $\frac{3}{4}$-in. or 1-in. diameter pipelines and hoses, and is suitable for working pressures up to 300 lb. per square inch.

As may be seen from the accompanying illustration, the connector comprises a female



body in which the male adaptor for the main air-supply pipe is engaged, and a spring-loaded valve shuts off the air supply when the hose adaptor is not coupled up. The hose adaptor is arranged to swivel within the coupling to prevent kinking of the hose. When disconnecting either the hose or the pipe adaptor, the back pressure is slowly and automatically released eliminating any danger of built-up pressure. The connector is precision made, and all steel parts are heavily plated. Gland and joint rings ensure that the unit is airtight.

Labour Notes

INDUSTRIAL PROGRESS IN WALES

Among other encouraging aspects of the industrial situation in Wales and Monmouthshire referred to in the latest report on Government action in that area are a record high level of employment, an increasingly high rate of production in most of the basic and manufacturing industries and a remarkable recovery by the tin-plate industry from its recession of last year.

In the past, Wales was an area in which the inhabitants relied for their livelihood mainly on a few staple industries and, when those industries were affected by severe unemployment, there was no other work to which they could turn. The unhappy condition in which the population was placed, owing to the lack of employment, was eventually recognised and, under the provisions of the Special Areas (Development and Improvement) Acts of 1934 and 1937, special commissioners were appointed for the purpose of organising schemes for the economic development and social improvement of the area and its people.

More recently, this legislation was reinforced by the passing of the Distribution of Industry Act of 1945, which was intended to provide added impetus and a wider application to the principles which had already been adopted. The principal objective of the Act was to secure such a distribution of industry throughout the country as a whole as would stimulate industrial developments in areas which were specially liable to suffer from unemployment.

IMPACT OF REDUNDANCY SOFTENED

The difference between the Welsh industrial situation of the past and that existing at the present time is commented upon in a leading article in the November issue of *Man and Metal*, the official journal of the Iron and Steel Trades Confederation, published on Monday.

Referring to the recent report on Welsh industry, the journal states that the "stimulating picture" therein recorded "provides a bright contrast to the situation between the wars when Wales was a depressed area and unemployment condemned whole communities to a life of poverty and humiliation."

South Wales, it is pointed out, provides a good illustration of the extent to which the object of the Distribution of Industry Act has been achieved, and the resilience already displayed by Welsh industry in absorbing workpeople in the tin-plate industry, who became redundant during 1953, is of the utmost significance.

The impact of redundancy is being softened for the older tin-plate operatives by grants from the "tin-plate labour fund," which at present totals about £500,000. Already, hundreds of employees have benefited from the fund, which manufacturers have been building up since 1946 by a levy of a penny for each box of tin-plates produced.

But, the journal concludes, the main problem of redundancy in the industry, though likely to be less serious than at first feared, is still to come. Plans to absorb the able-bodied mill workers who will be displaced during the next few years must be made now.

WAGE DEMANDS BY WOMEN ENGINEERING EMPLOYEES

Claims which would have the result of raising the basic wage rate of women employed in the engineering industry by £1 7*s.* 8*d.* a week were presented to the Engineering and Allied Employers' National Federation, on November 10, by the unions concerned. The principal concession asked for is that the minimum rate for women in the industry should be raised to a level at least equal to that of the labourer's rate for men.

The existing basic wage rate for women is £4 17*s.* 2*d.* a week and compares with one of £6 4*s.* 10*d.* a week for men labourers. The substantial advance in wages which the granting of such an increase would entail, would be further augmented by the addition of any rise in pay which might be given to the men as the result of the negotiations on their wage rates, which are due to commence next month.

Another request by the unions concerned is that discussions on rates for women employed on work requiring more than a labourer's skill should be begun in the near future.

Similar demands have been presented to the employers on various occasions in the past and rejected on the grounds of impracticability. It is contended that it would be uneconomic to pay women at the same rates as men, mainly because the training of women is more expensive, owing to the short time that many of them remain at work before leaving to get married, and because women require more supervision and have a higher rate of absenteeism than men.

LABOUR PROBLEMS OF THE WORLD'S METAL TRADES

General agreement on a series of practical measures for securing full co-operation between labour and managements in the world's metal-working establishments was obtained at the fifth session of the International Labour Organisation's metal trades committee, which was held at Geneva from October 25 until November 5.

The memorandum setting out the committee's conclusions on this subject was adopted by 91 votes to eleven. It established the principle that co-operation at plant level should be based on the participation of freely-elected workpeoples' representatives and declared that good human relations were inseparable from good industrial relationships.

Subjects considered by the committee to be suitable for joint consultations included accident prevention, hygiene, vocational training, welfare and social facilities, services rendered by employees, and employment questions of both a general and local character.

Stress was placed on the principle that co-operation between the two sides of the industry must not interfere with the normal functions of organisations of employers, or of trade unions as the representatives of workpeoples' interests. The part to be played by the unions was also emphasised in the memorandum, which declared that there should be genuine two-way communication at all levels in every undertaking.

In the committee's opinion, managements at the highest levels should be actively associated with the form of consultation and co-operation adopted, in view of their continuing responsibility to their undertakings for decisions, and for giving effect to trade agreements and legal requirements.

TRADE CYCLES AND UNEMPLOYMENT

A much smaller measure of agreement attended a report by the committee on ways to regularise production and employment in the world's metal trades at a high level, although it was eventually carried by 71 votes to 33, with three abstentions.

The majority of the committee's members took the view that sharp economic crises leading to widespread unemployment were avoidable. They expressed the belief that prolonged full employment could only be secured by the construction of a strong economic foundation, consisting of adequate consumer purchasing power, steadily rising living standards, the rapid advancement of under-developed countries, and the greater economic security of individuals, especially of those in the lower income groups.

It was urged that when there was danger of widespread unemployment in the metal trades, prompt attention should be given to such measures as price reductions resulting from increased productivity, decreased sales and reduced taxation, as well as to measures intended to increase the volume and stability of consumer credit.

Another suggestion put forward was that undertakings should carefully examine their programmes of capital expenditure over a period of years, in order that these investment schemes might be continued even if there were "minor adverse changes in business conditions." The committee also proposed that purchases and investments by Government departments and local authorities should be so timed as to counteract, as far as possible, fluctuations in demands for metal goods by private firms.

The committee consists of representatives from Governments and from each of the two sides of industry. Particulars of the delegates from the United Kingdom are given in our issue of November 5, page 611.

NEW WAGE CLAIM BY RAILWAY CONCILIATION STAFFS

Owing to the "intense dissatisfaction" expressed by rank-and-file members of the union with the wage agreement concluded between the National Union of Railwaymen and the British Transport Commission on October 8, a new demand by the union, for further wage payments, is to be presented to the Commission. The union's executive council announced on November 11 that they had decided that the existing agreement could not be accepted as final and that they had requested an early meeting with the Commission to discuss fresh proposals.

The new claim is designed to benefit some 260,000 railwaymen in the conciliation grades of British Railways' employees, but footplate men and salaried staffs will not be affected. The footplate men have put forward separate claims, which are to be the subject of an award by the Railway Staff National Tribunal, while the pay structure of the salaried staffs is to be further considered at joint meetings of representatives of the Transport Salaried Staffs' Association and the Commission.

MERCHANT NAVY ENGINEER OFFICERS' PAY AND CONDITIONS

A number of resolutions affecting the pay and conditions of technical officers in the British mercantile marine were due to be considered at the annual general meeting of the Navigators' and Engineer Officers' Union, which was held in London during yesterday and to-day.

Among the motions put forward on pay, was one asking that the consolidated salary rate applicable to senior officers on coastwise vessels, under section "b" of the existing agreement in the industry, should be abolished, and that the union should commence negotiations immediately with the owners for the hours of employment of such officers to be regulated.

One proposal was that apprentices who failed to pass the examination for second mate should be granted an able seaman's certificate without further testing, if the examiner approved.

Another motion, apparently intended to apply to all officers, suggested that service within twelve months in one company should be adopted as the basis for calculating annual leave.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

BOURNEMOUTH
"Electronics in the Modern Aircraft," by C. J. Foote. Bournemouth Branch. Grand Hotel, Bournemouth. Mon., Nov. 22, 8.15 p.m.

British Institution of Radio Engineers

LONDON
"The Development and Design of Direct-Coupled Oscilloscopes for Industry and Research," by M. J. Goddard. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Nov. 24, 6 p.m.

Chemical Society

CARDIFF
"The Chemistry of Allenic Systems," by Professor E. R. H. Jones. South Wales Branch. University College, Cardiff. Mon., Nov. 22, 5.30 p.m.
EXETER
"Applications of Electron Diffraction to Problems in Inorganic Chemistry," by Dr. L. E. Sutton. Exeter Branch. Washington Singer Laboratories, Exeter. Fri., Nov. 26, 5 p.m.

Illuminating Engineering Society

BATH
"Lighting for Enjoyment," by T. O. Freeth. Bath and Bristol Centre. Offices of the South Western Electricity Board, Old Bridge-street, Bath. Fri., Nov. 26, 7 p.m.
BIRMINGHAM
"Gemology," by F. Hessling. Birmingham Centre. Regent House, St. Phillip's-place, Colmore-row, Birmingham. Thurs., Nov. 25, 6 p.m.
LEEDS
"New Lamps, New Uses and New Lighting Techniques," by R. V. Mills. Leeds Centre. E.L.M.A. Lighting Service Bureau, 24 Aire-street, Leeds 1. Mon., Nov. 22, 6.15 p.m.
LEICESTER
"The History and Development of Lighting," by L. H. Hubble. Leicester Centre. Offices of the East Midlands Electricity Board, Charles-street, Leicester. Mon., Nov. 22, 6 p.m.

Incorporated Plant Engineers

BIRMINGHAM
"Laundries," by G. N. Freck. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Nov. 26, 7.30 p.m.
SHEFFIELD
Discussion on "Compressed Air in Industry." Sheffield Branch. Grand Hotel, Sheffield. Thurs., Nov. 25, 7.30 p.m.

Institute of Fuel

LONDON
"Peat-Fired Power Stations," by W. Cronin and J. F. Lang. Institution of Civil Engineers, Great George-street, S.W.1. Thurs., Nov. 25, 5.30 p.m.

Institute of Marine Engineers

BARROW-IN-FURNESS
"Air Conditioning of Ships," by J. K. W. MacVicar. Junior Lecture. Merseyside and North-Western Section. Technical College, Barrow-in-Furness. Fri., Nov. 26, 7.30 p.m.
MIDDLESBROUGH
"Automatic Boiler Controls," by Ll. Young. North-East Coast Section. Cleveland Scientific and Technical Institution, Middlesbrough. Thurs., Nov. 25, 6.15 p.m.

Institute of Metals

BIRMINGHAM
"The Working of Metals," by J. G. Wistreich. Birmingham Local Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Nov. 25, 6.30 p.m.
SHEFFIELD
"High Temperature Water-Cooling of Open-Hearth Furnaces by Means of Steam-Producing Elements," by F. J. Feltoe and P. M. Moreton; and "The Cooling of Large Rolling Mill Drives," by P. M. Moreton. Sheffield Local Section. University Buildings, St. George's-square, Sheffield. Wed., Nov. 24, 6.30 p.m.

Institute of Physics

LONDON
Discussion on "Fundamentals of Radiographic Definition, Resolution and Unsharpness," opened by R. Halmshaw and Dr. G. Spiegler. Non-Destructive Testing Group. New Horticultural Hall, Vincent-square, S.W.1. Tues., Nov. 23, 2 p.m.

Institute of Refrigeration

LONDON
"The Use of Heat Pumps of Small Capacity for Various Purposes in Great Britain," by Miss M. V. Griffith. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Thurs., Nov. 25, 5.30 p.m.

Institute of Road Transport Engineers

DURHAM
Brains Trust Meeting. North East England Group. Whinney Hill Secondary School, Durham City. Tues., Nov. 23, 7 p.m.
EXETER
"Thin-Wall Bearings," by P. T. Holligan. Western Centre. Rougemont Hotel, Exeter. Tues., Nov. 23, 7.30 p.m.

Institution of Chemical Engineers

MANCHESTER
"Adiabatic Absorption of Hydrogen Chloride," by T. A. Kantyka and H. R. Hinchlieff. North-Western Branch. College of Technology, Manchester. Mon., Nov. 22, 3 p.m.

Institution of Civil Engineers

LONDON
"Standardisation of Type and Design Applied to Steam-Locomotive Shed Roofs," by V. F. Beer; and "Smoke Extraction from Engine Sheds: An Account of Some Full-Scale Tests," by R. L. McIlmoyle and D. W. Peacock. Tues., Nov. 23, 5.30 p.m.
MANCHESTER
Discussion on "First Years of Professional Employment." Students' Meeting. North-Western Association. Engineers' Club, Albert-square, Manchester 2. Tues., Nov. 23, 6.30 p.m.

Institution of Electrical Engineers

LONDON
Discussion on "Plastics for the Radio Engineer." Radio Section. Mon., Nov. 22, 5.30 p.m.
"The Application of the Hall Effect in a Semi-Conductor to the Measurement of Power in an Electro-Magnetic Field," by Professor H. E. M. Barlow; "Audio-Frequency Power Measurements by Dynamometer Wattmeters," by Dr. A. H. M. Arnold. Measurements Section. Tues., Nov. 23, 5.30 p.m.
"Attitudes of Mind," by A. R. Cooper. London Students' Section. Tues., Nov. 23, 6.30 p.m.
"Supervisory Equipment for the Indication of Shaft Distortion in Steam Turbines," by D. Antrich, H. W. B. Gardiner and R. K. Hilton; and "The Electrical Measurement of Steam-Turbine Rotor Movements, with Special Reference to the Operation and Design of Modern Power Plant," by J. L. Ashworth, J. S. Hall and A. H. Gray. Supply Section. Wed., Nov. 24, 5.30 p.m.
KETTERING
"Safety in the Use of Portable and Transportable Electrical Equipment in Industry," by J. W. Bunting. East Midland Centre. George Hotel, Kettering. Thurs., Nov. 25, 6.30 p.m.
LEICESTER
"A Radio Position-Fixing System for Ships and Aircraft," by C. Powell. East Midland Centre. College of Technology, Leicester. Fri., Nov. 26, 6.30 p.m.
MALVERN
"Colour Television," by C. J. Hirsch. South Midland Centre. Winter Gardens Restaurant, Great Malvern. Thurs., Nov. 25, 7.15 p.m.
NEWCASTLE-UPON-TYNE
"Service Experience of the Effect of Corrosion on Steel-Cored-Aluminium Overhead-Line Conductors," by Dr. J. S. Forrest and J. M. Ward. North-Eastern Centre. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., Nov. 22, 6.15 p.m.
NOTTINGHAM
"Telemetering for System Operation," by R. H. Dunn and C. H. Chambers. East Midland Centre. Gas Board's Demonstration Theatre, Nottingham. Tues., Nov. 23, 6.30 p.m.
WEYMOUTH
"Electric Fuses and Circuit Breakers," by E. W. Baxter. Southern Centre. Technical College, Weymouth. Fri., Nov. 26, 6.30 p.m.

Institution of Mechanical Engineers

LONDON
Discussion on "Transmissions for Small European Cars." Automobile Division. Wed., Nov. 24, 6.45 p.m.
"Dynamic Stresses in Electric Overhead Travelling Cranes, Due to the Hoisting and Lowering of Loads," by E. Lightfoot and Dr. B. L. Clarkson. Applied Mechanics Group. Fri., Nov. 26, 5.30 p.m.
BRISTOL
"Engine Research and Development as a Service to Industry: A Personal Experience," by J. H. Pitchford. Western Automobile Centre. Royal Hotel, Bristol. Tues., Nov. 23, 6.45 p.m.
CHESTER
"Some Problems in Lubrication and the Substances Called Additives," by A. Towle. North-Western Automobile Centre. Grosvenor Hotel, Chester. Thurs., Nov. 25, 7.15 p.m.
GLASGOW
Repetition of Presidential Address by Dr. R. W. Bailey. Scottish Branch. Royal Technical College, George-street, Glasgow. Wed., Nov. 24, 7.30 p.m.
SEVENOAKS
James Clayton Lecture on "Nuclear Reactors and Power Production," by Sir Christopher Hinton, read by Dr. J. M. Kay. Southern Branch. Cornwall Hall, The Drive, Sevenoaks. Wed., Nov. 24, 7 p.m.
SHEFFIELD
"High-Temperature Water-Cooling of Open-Hearth Furnaces by Means of Steam-Producing Elements," by F. J. Feltoe and P. M. Moreton; and "The Cooling of Large Rolling-Mill Drives," by P. M. Moreton. Yorkshire Branch. Mappin Hall, The University, St. George's-square, Sheffield. Wed., Nov. 24, 6.30 p.m.

Institution of Production Engineers

LINCOLN
Discussion Meeting. Lincoln Section. Technical College, Lincoln. Thurs., Nov. 25, 7.30 p.m.
SHEFFIELD
Informal Meeting. Sheffield Section. Grand Hotel, Sheffield. Mon., Nov. 22, 6.30 p.m.
SHREWSBURY
"Patents and the Registering of Designs," by S. J. Parker; and "Human Safety in Engineering," by B. G. Williams. Shrewsbury Section. Shrewsbury Technical College, Shrewsbury. Wed., Nov. 24, 7.30 p.m.

Institution of the Rubber Industry

MANCHESTER
"Practical Safety Precautions in the Rubber Industry," by E. Morris. Manchester Section. Engineers' Club, Albert-square, Manchester. Mon., Nov. 22, 6.15 p.m.

Institution of Structural Engineers

LONDON
"The Design and Construction of the Nuclear Reactor Buildings at Windscale Works, Sheffield," by D. R. R. Dick. Thurs., Nov. 25, 6 p.m.
BIRMINGHAM
"Structural Uses of Timber," by S. Woolf. Midland Counties Branch. James Watt Memorial Institute, Birmingham. Fri., Nov. 26, 6 p.m.

Junior Institution of Engineers

LONDON
Annual General Meeting. Fri., Nov. 26, 7 p.m.
MANCHESTER
"Practice," by C. R. Gundersen. North-Western Section. Engineers' Club, Albert-square, Manchester. Mon., Nov. 22, 7.30 p.m.

Manchester Association of Engineers

MANCHESTER
"Submarine Telegraph and Telephone Cables," by F. Mattingley. Engineers' Club, Albert-square, Manchester. Fri., Nov. 26, 6.45 p.m.

Manchester Metallurgical Society

MANCHESTER
"Some Experiences in Industrial Research," by Dr. B. P. Dudding. Central Library, Manchester. Wed., Nov. 24, 6.30 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
"The Use of a Digital Computer, with Particular Reference to the Analysis of Structures," by Dr. R. K. Livesley and T. M. Charlton. Mining Institute, Newcastle-upon-Tyne. Fri., Nov. 26, 6.15 p.m.

Reinforced Concrete Association

GLASGOW
"The Use of Reinforced Concrete in the Gas Industry," by S. V. Gardner. Royal Technical College, George-street, Glasgow. Thurs., Nov. 25, 6.30 p.m.

Royal Aeronautical Society

LONDON
"The Development and Investigation of Fatigue Cracks," by N. Thompson. Thurs., Nov. 25, 7 p.m.

Royal Meteorological Society

EDINBURGH
"Statistical Methods Applied to Upper-Air Work," by Mrs. Helen Goldie. Scottish Centre. Department of Natural Philosophy, Drummond-street, Edinburgh 8. Fri., Nov. 26, 5 p.m.

Royal Society of Arts

LONDON
"A Scheme for Roof-Top Roadways," by Wing-Commander T. R. Cave-Browne-Cave; and "A System for Underground Roadways for London," by C. E. H. Watson. Wed., Nov. 24, 2.30 p.m.

Royal Statistical Society

SHEFFIELD
"Reasons for Failure," by K. F. Lane. (Illustrated by the example of an ingot mould.) Sheffield Industrial Applications Group. Grand Hotel, Sheffield. Thurs., Nov. 25, 6.30 p.m.

Sheffield Metallurgical Association

SHEFFIELD
"Chemical Analysis: Some Physical-Chemical Considerations," by C. E. A. Shanahan. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield 3. Tues., Nov. 23, 7 p.m.

Sheffield Society of Engineers and Metallurgists

SHEFFIELD
"High-Temperature Water-Cooling of Open-Hearth Furnaces by Means of Steam-Producing Elements," by F. J. Feltoe and P. M. Moreton; and "The Cooling of Large Rolling-Mill Drives," by P. M. Moreton. Mappin Hall, University of Sheffield, St. George's-square, Sheffield. Wed., Nov. 24, 6.30 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3 (ROYal 8493.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institute of Physics, 47 Belgrave-square, London, S.W.1. (SLOane 9806.)
Institute of Refrigeration, Dalmeny House, Monument-street, London, E.C.3. (MINcing Lane 6851.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Manchester Association of Engineers, 20 Booth-street, Manchester 2. (Central 2796.)
Manchester Metallurgical Society, The Kennedy Press, Ltd., 31 King-street West, Manchester 3.
North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne 1. (Newcastle 20289.)
Reinforced Concrete Association, 94-98 Petty France, London, S.W.1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Meteorological Society, 49 Cromwell-road, South Kensington, London, S.W.7. (KENsington 0730.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2366.)
Royal Statistical Society, 21 Bentinck-street, London, W.1. (WELbeck 7638.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield 7. (Sheffield 53674.)
Sheffield Society of Engineers and Metallurgists, University of Sheffield, St. George's-square, Sheffield 1. (Sheffield 24071.)

★ ★ ★

HYDRAULIC RESEARCH

New Laboratory at Stockholm

A new laboratory is to be built and installed for the Institute of Hydraulics at the Royal University of Stockholm. The Swedish Government are allocating Kr. 1,200,000 towards the cost, and 26 private and municipal power companies have contributed Kr. 265,000 for instruments and other technical equipment. Most of the floor space will be used for building and testing models of waterworks projects, and the equipment is to include two large reservoir tanks and a pipe network for supplying water to the models at a maximum rate of 1·2 cub. m. (42 cub. ft.) per second.